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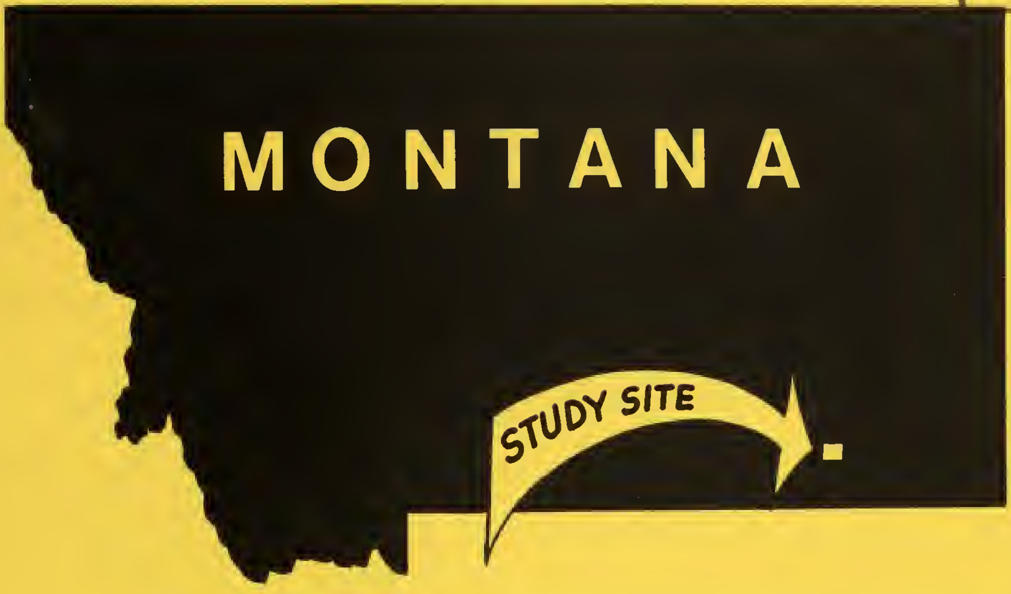

RESOURCE and POTENTIAL RECLAMATION EVALUATION

OTTER CREEK STUDY SITE

EMRIA
REPORT #1
1975

UNITED STATES DEPARTMENT OF THE INTERIOR — BUREAU OF LAND MANAGEMENT

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OTTER CREEK STUDY SITE
OTTER CREEK COALFIELD, MONTANA

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RESOURCE AND POTENTIAL RECLAMATION EVALUATION
OF
OTTER CREEK STUDY SITE
OTTER CREEK COALFIELD, MONTANA

INTRODUCTION

A growing and affluent society is creating an ever increasing need for energy. Attention has focused on the energy fuels sources existent in the western states, primarily the Rocky Mountain and the Northern Great Plains Coal Provinces, due to the abundance, ease of extraction, and the quality of the resources present. It is the responsibility of the Bureau of Land Management to assist in meeting these energy demands and, at the same time, provide sound reclamation and rehabilitative guidelines so that the lands subjected to disturbance are returned to a restored and useful condition.

Purpose

The purpose of this study is to assure adequate base line data for choosing optimum reclamation and rehabilitative objectives and for establishing appropriate data and interpretation for preparation of lease stipulations through site-specific pre-planning recommendations for mining and reclamation.

Objectives

1. To analyze and quantify environmental impacts from surface mining of energy and other minerals in Colorado, Montana, New Mexico, North Dakota, Utah, and Wyoming.

2. To provide resource and impact information to the leasing site selection procedures as set forth by the Secretary of the Interior.

3. To provide environmental resource information needed to implement effective reclamation and rehabilitation programs and for the development of meaningful lease stipulations as required by the mined land reclamation program.

4. To provide resource and impact information to support state and local regional development and land use planning efforts.

5. To determine the present and potential capability of the soil and geologic strata to support and maintain vegetation on known energy fuel deposits.

6. To provide physical and chemical data from which realistic stipulations may be prepared for energy mineral exploration, mining, and reclamation plans.

7. To provide data needed in the preparation of Environmental Impact Statements, Environmental Analysis Records, and to aid in the review of mining and reclamation plans for proposed land disturbing activities in the vicinity of the study.

Authority

Public Land Administration Act of July 14, 1960 (74 Stat. 506).

Responsibility

Bureau of Land Management

a. Select reclamation study site areas for coordinated investigation of vegetation, soil, geological structure, surface water, and ground water.

b. Acts as Contracting Officer in the coordination, establishment, and execution of work orders.

c. Reviews and consolidates work order and field office data and prepares input to reports published by the Bureau of Reclamation.

d. Procurement of easements and rights-of-way to conduct the studies.

e. Distributes technical data, reports, and reclamation and rehabilitation recommendations to Bureau of Land Management field offices.

Bureau of Reclamation

a. Conducts soil inventories.

b. Conducts drilling operations for the procurement of core samples to be used for the analysis of geological strata in overburden materials.

c. Installs casing in holes selected for ground-water observation wells.

d. Characterizes and interprets overburden materials as well as substrata immediately below the coal resources.

e. Conducts greenhouse studies for determining overburden materials potential for supporting vegetative growth.

f. Conducts mechanical weathering tests of core samples to determine stability of overburden materials.

g. Recommends to district office, Bureau of Land Management, suitable plant species for use in areas to be reclaimed.

h. Advises district office, Bureau of Land Management, on reclamation techniques.

i. Prepares a geologic map.

Geological Survey

a. Conducts vegetation and soil studies which will result in vegetation maps and related soil characteristics.

b. Assesses reclamation potential based on water available from precipitation, the effects of surface mining on area hydrology, and the measures required to prevent adverse effects on surface and ground waters of the area.

c. Prepares sediment yield maps.

d. Prepares erodibility maps.

e. Estimates annual runoff and peak flows.

f. Collection and interpretation of data to predict alternative solutions to ground-water problems encountered during mining and reclamation.

g. Implementation of a monitoring system to define base line conditions and to document ground-water changes in flow and quality caused by mining and reclamation.

h. Prepares potentiometric maps.

i. Coal sections and well logs.

j. Coalbed maps showing coal resources.

k. Tabulation of coal resources estimates.

l. Table of analytical results on coal resources.

m. Graphic presentation of analytical results.

    1) Vertical - Plotted against well logs.

    2) Horizontal - Plan view of significant.

General Description

The Otter Creek Study Site, Otter Creek Coalfield, is located in the southeastern corner of the State of Montana in Powder River County, approximately 6 miles southeast of Ashland, Montana. The general location of the site is shown on plate 1. The site is comprised of approximately 1830 acres in Sections 26 and 34, Township 3 South, Range 45 East, and Section 2, Township 4 South, Range 45 East, Montana Principal Meridian. The coal resources underlie about 1200 acres within the site, but the detailed land classification survey covered about 1300 acres. This should provide full coverage of land that may be surface mined. The location and setting of the study site is shown on photograph 1 and plate 2. The surface is privately owned on the three sections; however, most minerals, including all coal, are federally owned. The ownership status of all minerals is shown on plate 3.

Prior to the 1870's, this area was occupied by various tribes of plains Indians. The land provided for and satisfied their physical, sociological, and cultural needs. These people fought desperately to retain these lands which were being "invaded" by the white man. The resultant disposition of lands included the establishment of two reservations, the Crow and the Northern Cheyenne. The eastern boundary of the Northern Cheyenne Reservation lies approximately 10 miles west of the study site. The population density is one person per square mile. The area is steeped in significant Indian cultural values and historical occurrences. Archeological inventories have identified numerous significant sites. None were disturbed by these studies; however, it is recommended that a more intensive investigation be conducted prior to any surface mining.

The site is comprised of six vegetative communities as follows:

Pine Savannah

Grassland-Shrubland

Breaks

Hay Meadows

Crested Wheatgrass

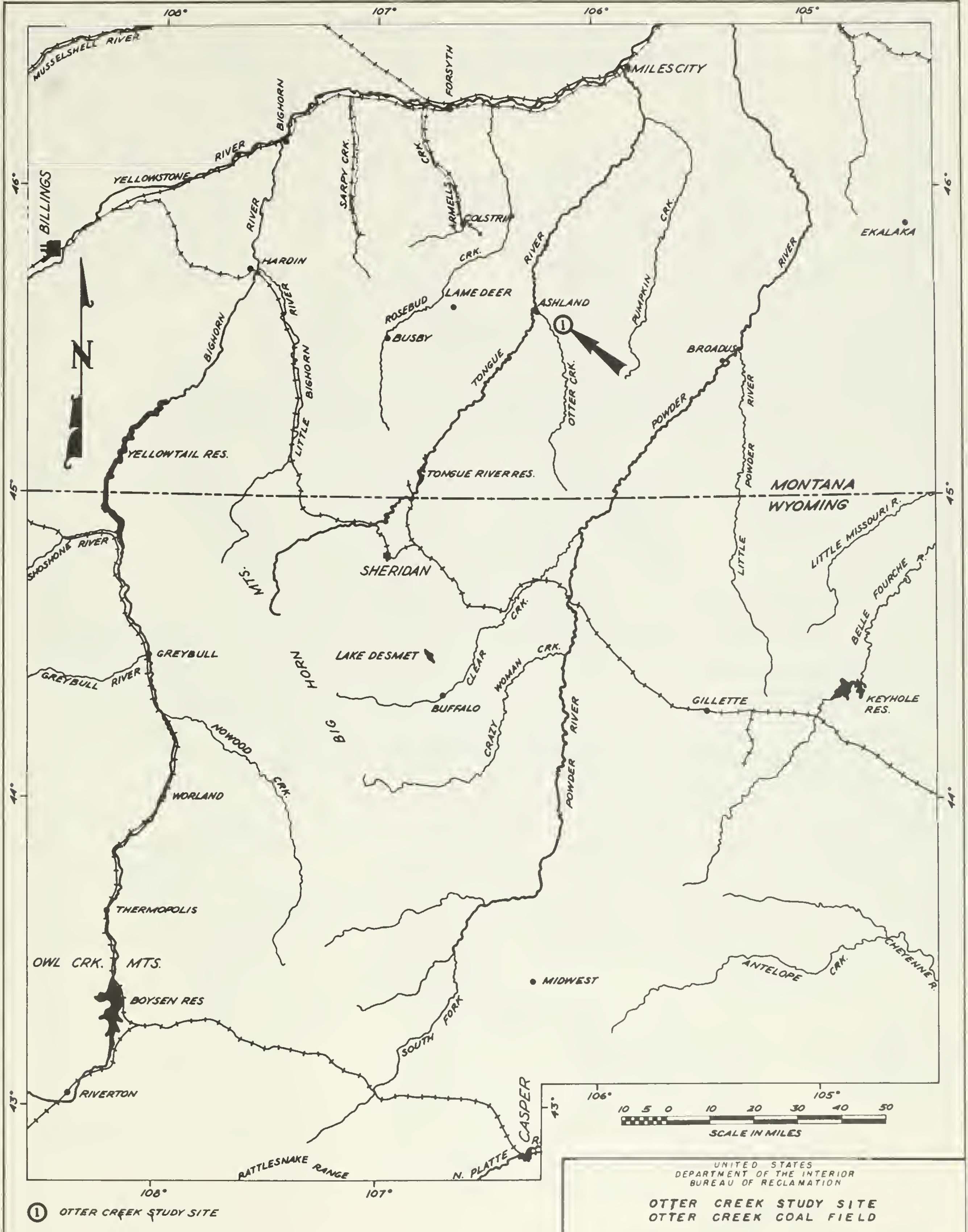
Cultivated Land

All contribute to the major industry which is raising livestock. A small sawmill in Birney handles the bulk of the timber sold in the area. The greater portion of the mill by-products are used locally in the form of fence posts, corral poles, bridge timbers, and outbuilding construction.

The area has one of the highest population densities of deer in the state. Both mule and whitetail deer are present. The mule deer tend to inhabit the higher pine savannah grassland-shrub communities while the whitetail deer tend to occupy the lower hay meadows-cultivated lands along the Tongue River drainways. Other game species include ring necked pheasant, Hungarian partridge, cougar, pronghorn antelope, sharptail and sage grouse. Some of the primary nongame species include coyote, prairie dogs, porcupine, bobcat, jackrabbits, and various rodents. There are no perennial-waters located on the site; however, should this area be mined, sediment contributions resulting from uncontrolled runoff could have significant impacts on downstream fisheries habitat since discharges drain into Otter Creek which is tributary to the Tongue River. Waters capable of supporting fish are confined to the Tongue River Reservoir, its downstream watercourses, and numerous impoundments constructed primarily for watering livestock. Due to the fluctuations in water levels and temperature resulting from irrigation, the occurrence of salmonoids is by artifical stocking. The primary species are sauger, catfish, bullheads, crappie, perch, and various "rough" fish such as carp and suckers.

The major recreational use is in the form of sightseeing. Montana Highway 212 passes through the area approximately 6 miles north of the study site. This highway provides access for tourists through the Crow and Northern Cheyenne Reservations. It is also a direct route to the Black Hills from the north.

PLATE 1



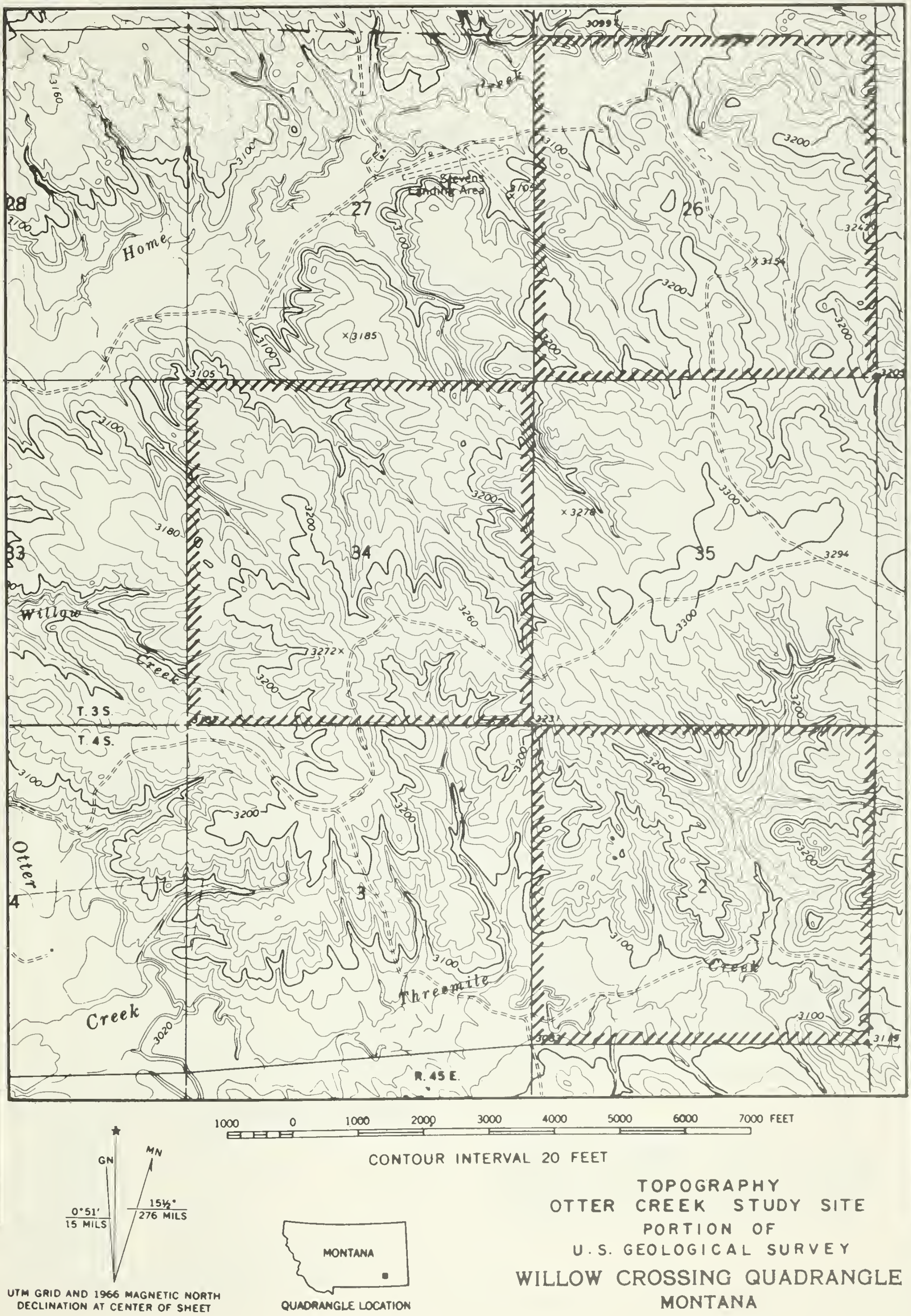
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

OTTER CREEK STUDY SITE
OTTER CREEK COAL FIELD

GENERAL LOCATION MAP

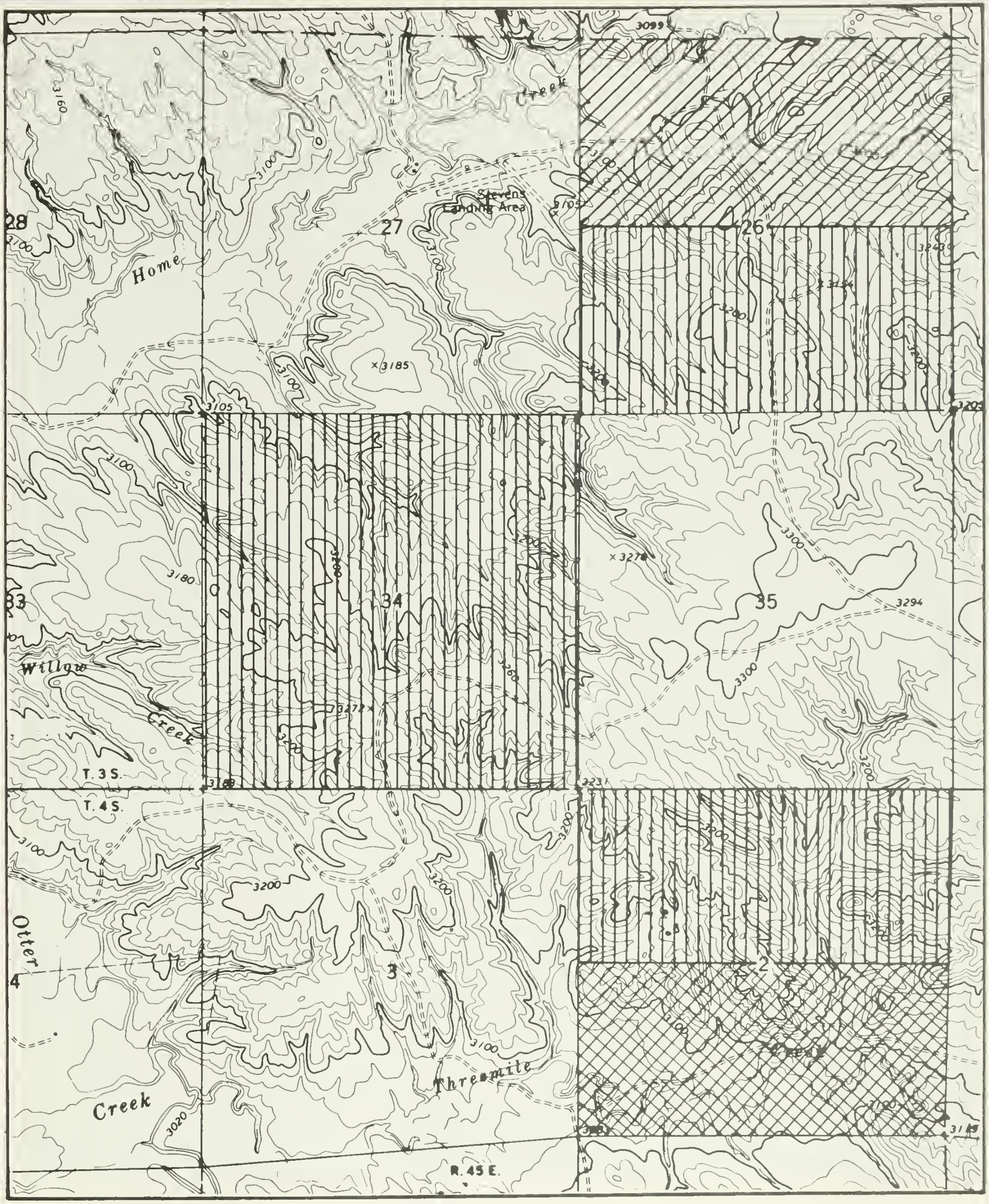
GEOLOGY ________ SUBMITTED ________
DRAWN GJ TAUCHER RECOMMENDED ________
CHECKED ________ APPROVED ________

BILLINGS, MONTANA FEBRUARY 1975 1305-600-1



CONTOUR INTERVAL 20 FEET

TOPOGRAPHY
OTTER CREEK STUDY SITE
PORTION OF
U. S. GEOLOGICAL SURVEY
WILLOW CROSSING QUADRANGLE
MONTANA

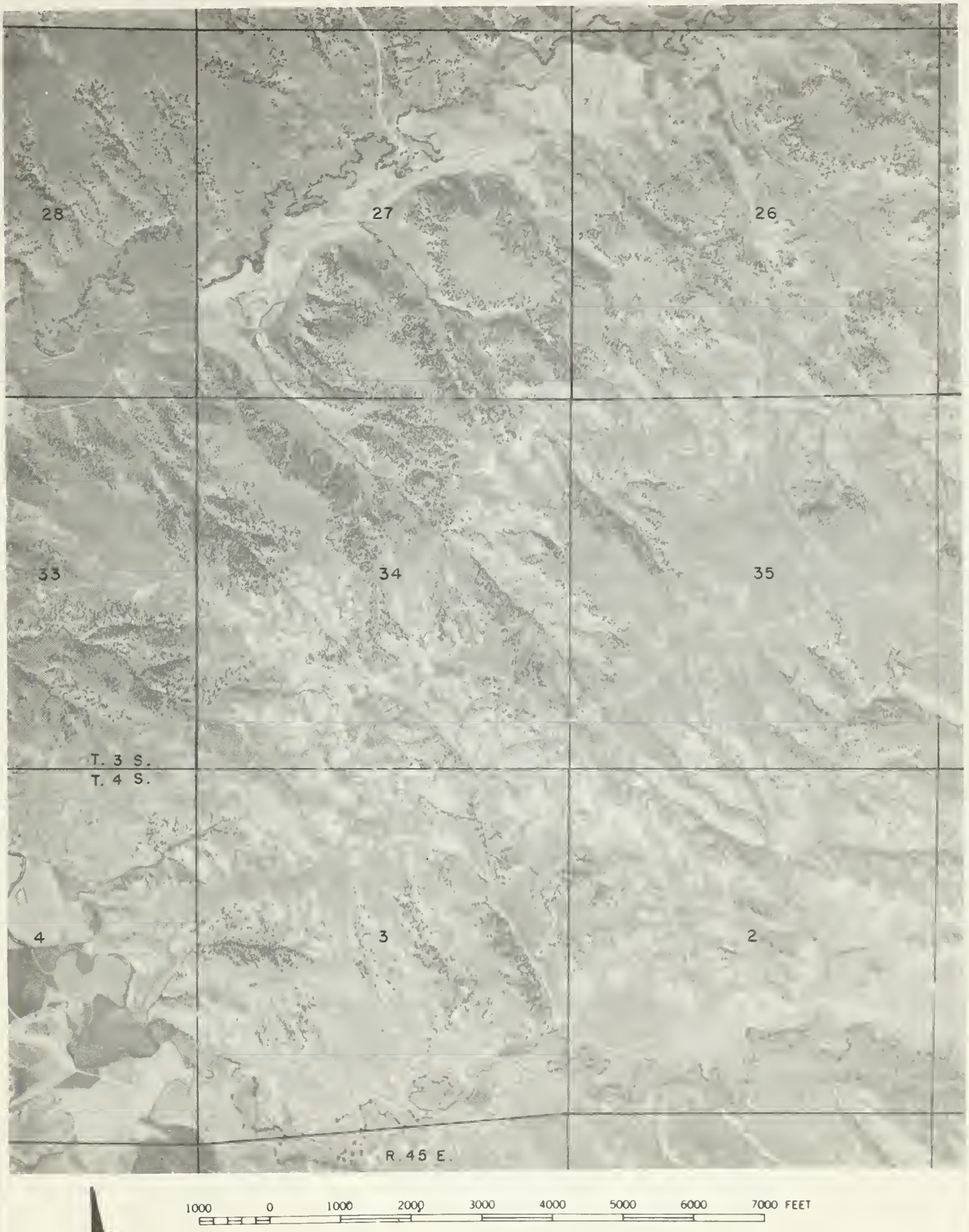


MINERALS OWNED BY THE FEDERAL GOVERNMENT

SYMBOL	MINERAL RIGHTS
▥	ALL MINERALS
▨	COAL ONLY
▩	OIL, GAS & COAL ONLY

ALL SURFACE PRIVATELY OWNED

OTTER CREEK STUDY SITE
OTTER CREEK COAL FIELD
MINERAL STATUS MAP



Photograph 1 - Aerial view of the Otter Creek study site (Secs. 26 and 34, T. 3 S., R. 45 E. and Sec. 2, T. 4 S., R. 45 E.). A portion of the Otter Creek Valley is shown in the lower left corner of the photograph. This photograph is a portion of the Bureau of Land Management Photograph RCAP - 7-2 (6/28/74).

TOPOGRAPHY

Distinctive sandstone ridges, mesas, and escarpments, dominate much of the landscape in these undulating and hilly uplands in and around the Otter Creek site. Erosional forces have developed a branching drainage pattern that flows generally northward to the Yellowstone River. These natural drains empty into Otter Creek which is the only perennial stream near the study area. It has a moderately wide alluvial valley with an incised channel.

Two tributaries of Otter Creek extend eastward into the study area. Home Creek is on the north and Threemile Creek Valley forms the south edge of the area. These alluvial valleys are lined by fans, foot slopes, and stream terraces. Drainage ways extending outward from these creeks in a branching pattern have eroded the beds of Fort Union Formation in varying degrees. Many gullies with steep sides and rounded or sharp ridges have developed. Erosion at the gullies continues to cut into the softer geologic beds that underlie the uplands and tabular divides. Resistant ledge forming sandstone borders most of the tabular divides and many raw shale exposures occur just below the sandstone bluffs. The smooth, very gentle slopes of the tabular divides blend into the undulating and hilly uplands.

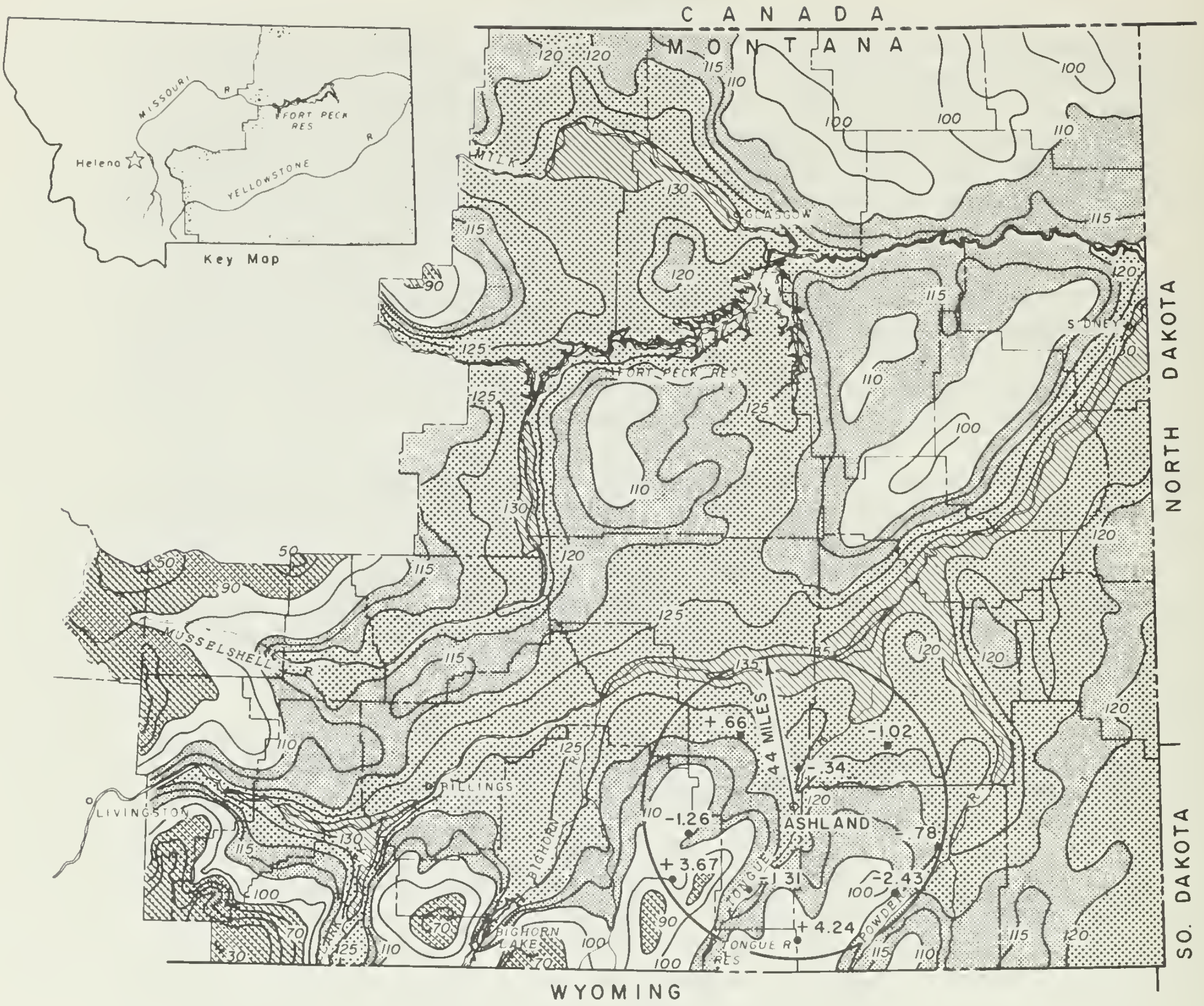
The elevation of the study area ranges from 3,065 feet on Threemile Creek to 3,272 feet at the highest point in the study area. This high point is 1,200 feet north of the south 1/4 corner of Sec. 34, T. 3 S., R. 45 E.

CLIMATE

The Otter Creek site has a continental-type climate. It is cold in the winter, warm in the summer and large diurnal variations are common. Elevation at the site ranges from 3,065 feet to 3,272 feet. The Broadus weather station at elevation 3,030 feet receives 14.2 inches average annual precipitation and Birney, at elevation 3,190 feet, receives an average of 13.7 inches annually. Torrential rainstorms are common and unprotected soil surfaces may erode severely during these storms. These storms, though common, may not cover large areas. Hailstorms occasionally cross the area, but these weather extremes do not place the area in any particular type storm belt. About 75 percent of the precipitation falls as rain during the growing season. Growth of native range is rapid during May and June which are the wettest months of the year.

The frost-free period (>32° F.) ranges from 108 days at Birney to 120 days at Broadus. The growing season for hardy grasses (28° F.) in average years begins May 10 at Birney and ends 131 days later on September 19. Following the spring rains, July is hot, dry and windy with excessive evaporation and evapotranspiration rates. Humidity is low. During the months of June, July and August, about 32 days have a temperature of 90° F. or higher. Additional temperature data are shown on table 1.

The climate in the Otter Creek area in most years is suited for reclamation of surface-mined land because the spring rains are generally adequate for establishing stands of native vegetation. The 13.7 to 14.2 inches of precipitation received in average years meet the requirement of range vegetation which grows rapidly in the late spring and early summer. This moisture from natural precipitation is usually depleted by established plants in 6 to 8 weeks and the plants mature and become dormant. Consumptive use data in table 2 shows native grasses could use 22.5 inches of moisture if available, but it also shows that 13.9 inches or the average annual precipitation could be used by July 15. Reclamation of surface-mined land is very difficult in areas that consistently receive 10 inches of precipitation or less each year. In this area years with less than 10 inches of annual precipitation are not common. The Broadus station reported less than 10 inches only three times in the last 37 years and Birney only once in the last 21 years. Variation in annual precipitation in the area is recorded on figures 1 and 2.



EXPLANATION

AVERAGE NUMBER OF DAYS WITHOUT KILLING FROST (32° F)

▩	30 - 90
☐	90 - 110
▒	110 - 120
░	120 - 130
▨	130 - 140
~115~	ISOLINE

NOTES

1. Isoline interval - 20 days below 90, 10 days 90 to 100, 5 days above 100.
2. 44 mile circle around Ashland indicates area in which average yearly precipitation is 15 inches Minus or plus (inside circle) indicates deviation from 15 inch normal at selected stations.

25 0 25 50 75
SCALE OF MILES

FROST FREE PERIODS
AND
PRECIPITATION DEVIATION AT
SELECTED LOCATIONS
IN EASTERN MONTANA

Figure 2

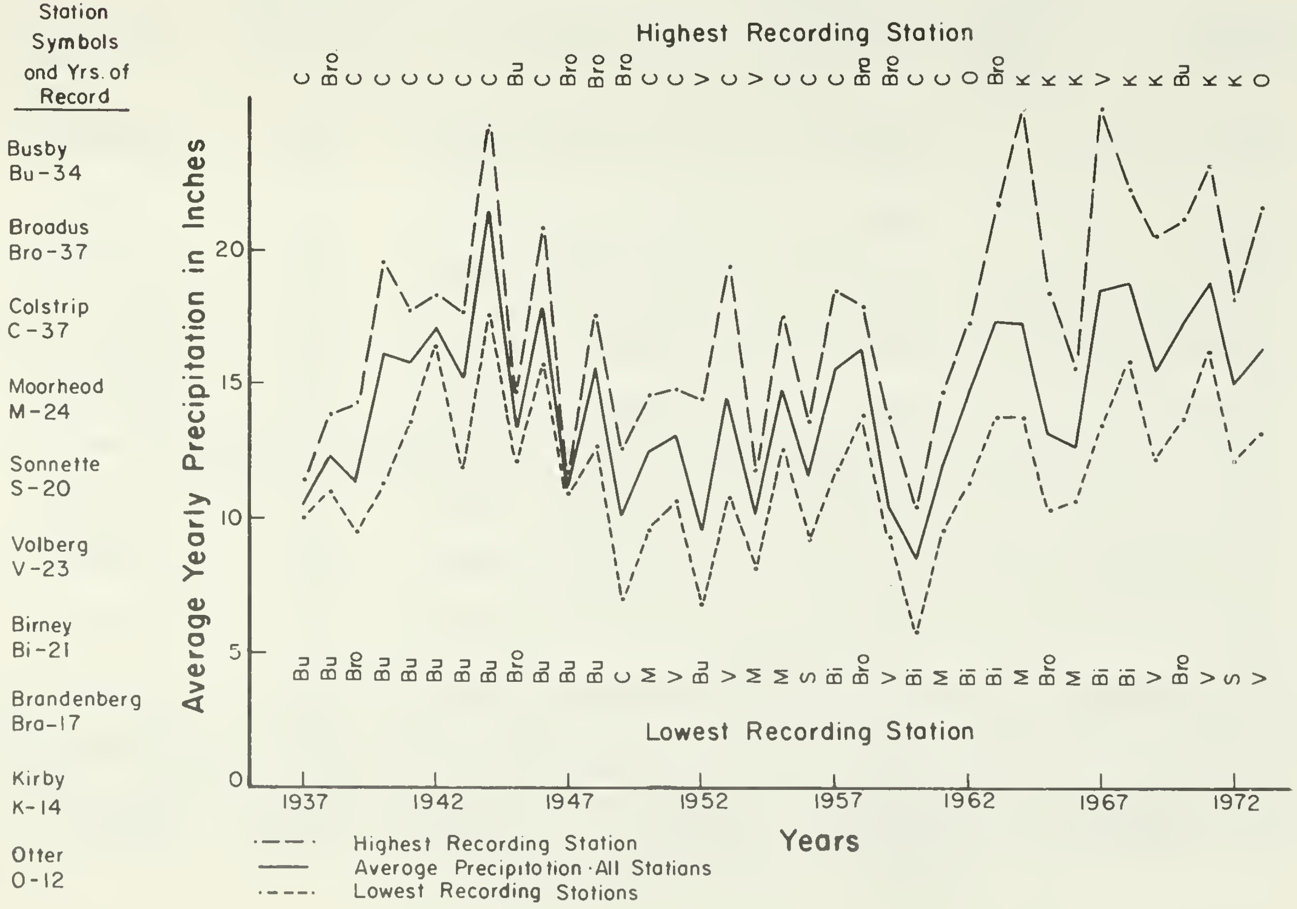


Figure 2. Relationship of Annuol Precipitotion ot Selected Stations

Table 1

Table 1. Number of Days Between Selected Temperatures

Station	Temp.	Average Dates Last in Spring	Average Dates First in Fall	Average Days Between	Remarks
Birney	32°	May 25 to	Sept. 10	108	19 year record
Birney	28°	May 10 to	Sept. 19	131	19 year record
Birney	24°	May 3 to	Oct. 2	153	19 year record
Birney	20°	April 17 to	Oct. 12	179	19 year record
Birney	16°	April 6 to	Oct. 27	204	19 year record
Broadus	32°	May 19 to	Sept. 16	120	26 year record
Broadus	28°	May 4 to	Sept. 27	146	26 year record
Broadus	24°	April 25 to	Oct. 7	166	26 year record
Broadus	20°	April 14 to	Oct. 20	189	20 year record
Broadus	16°	April 6 to	Nov. 1	209	20 year record

Table 2 - Potential Consumptive Use of Moisture and Available Moisture - Native Grasses 1/

Otter Creek Study Site

Month	Midpoint	Accumulative Days to Midpoint	Mean Air Temp. (°F)	Monthly Requirement Inches	Moisture Reserve Inches 2/	Precipitation Inches	Difference Inches 3/
May 4					+4.04		
	May 17	13	54.6	2.80		2.23	+3.47
June					+3.37		
	June 15	42	63.1	4.75		3.13	+1.85
July					+1.85		
	July 15	72	71.2	6.36		1.36	-3.15 4/
August					-3.15		
	Aug. 15	103	69.8	5.52		1.08	-7.59
Sept.					-7.59		
	Sept. 13	131	58.2	3.05		1.20	-9.44
Sept. 27		145					
				22.48		9.00	

1/ Computed by Blaney-Criddle Method using the Broadus Weather Station - Latitude 45°26'N
2/ Moisture Reserve = Summation of precipitation (Oct. to April) = 5.05 x 0.80 = 4.04 inches
3/ Difference = Moisture Reserve plus precipitation minus moisture use
4/ Natural precipitation during most years is inadequate to meet potential moisture needs. In average years, the plants use the available moisture by July 15 and mature and become dormant.

GEOLOGY

Regional Geology

The Otter Creek Coalfield is located in the northern part of the Powder River Basin in southeastern Montana. This basin, a part of the unglaciated portion of the Great Plains physiographic province, is about 225 miles long, extending from the Yellowstone River in Montana to the North Platte River in Wyoming. It is about 90 miles in width, bounded on the west by the Bighorn Mountains and on the east by the Black Hills. Structurally, the basin is an asymmetrical syncline with a northwestward trending axis between the cities of Douglas and Sheridan, Wyoming. South of the Montana-Wyoming border, the synclinal axis changes direction to a northeastward trend roughly following the Tongue River in the direction of Miles City, Montana. An estimated 18,000 feet of sediments overlie the basement complex in the deepest part of the basin north of Glenrock, Wyoming.

The geologic history of the area since Precambrian time includes periods of deposition, deformation, and erosion. During the Paleozoic and Mesozoic Eras, a sequence of carbonates, sandstones, and shales were deposited throughout Montana and Wyoming. Thickness of these sediments on the west side of the basin varies from 9,000 feet near Yellowtail Dam to 11,500 feet near Buffalo, Wyoming. About 6,500 feet of Paleozoic and Mesozoic sediments are present in the Black Hills area on the east side of the basin.

The area was relatively stable during these periods with deposition occuring generally under a marine environment. Deformation of these strata began with the Laramide Revolution near the close of the Mesozoic Era (Late Cretaceous), at which time mountain masses such as the Bighorns and Black Hills were uplifted. Uplift continued throughout Paleocene and gradually ended in Eocene time. Materials stripped from the mountains were deposited in fans or sheets across the basin floors, gradually burying the flanks of the mountains in their own debris. By the middle of the Cenozoic Era, the basins were largely filled and the mountains peneplained. In Pliocene time, a broad regional uplift occurred and continued intermittently into Pleistocene time. This uplift raised the previously developed peneplain surface to elevations of about 10,000 feet in the Bighorn Mountains. Streams rejuvenated by the uplift excavated the basins and exhumed the buried mountain masses.

Today, Precambrian rocks are exposed in the cores of the Black Hills and Bighorn Mountains. These rocks are surrounded by sediments of the Paleozoic and Mesozoic Age. The central part of the basin is filled with Cenozoic (Tertiary) sediments. Plate 4 is a generalized map of the regional geology of the basin area.

Site Geology

Investigations

All of the area involved in the Otter Creek study has been mapped by the U.S. Geological Survey and the Montana Bureau of Mines and Geology. Publications covering these investigations are listed in the bibliography.

Surface and subsurface investigations were conducted in the Otter Creek study area between July of 1974 and February of 1975. These investigations included both detailed land classification and inventory of the surface soils, mapping of the surface geology, and the drilling of eight holes ranging in depth from 146.1 feet to 413.8 feet Continuous cores were obtained from seven of the drill holes (DH 74-101 through -107) for geologic logging, the selection of samples of the bedrock overburden materials, and coal for laboratory analyses. Drill Hole 75-108 was completed outside the area as a water well for study of the area ground-water regimen. The site locations of the deep drill holes are shown on the Geologic and Investigations Map, plate 5. Geologic Profiles and detailed geologic logs of the drill holes are shown on plates 6 through 17.

All the deep drill holes were drilled to a depth of 20 to 30 feet below the Knoblock coalbed. Three of the holes (DH 74-101, -102, and -105) were drilled through the Flowers-Goodale coalbed. Samples for qualitative analyses of the coal were taken from all the major coalbeds.

Plastic pipes ranging from 2-inch inside diameter to 4-inch inside diameter were installed in the drill holes for the ground-water studies being conducted by the U.S. Geological Survey. This study will require several years to complete.

Detailed geologic mapping on a scale of 1 inch equals 1,000 feet was done in the field on aerial photographs. These data were transferred to a topographic map of the same scale and are shown on plate 5.

The core drilling was performed using a Failing Model 314 rotary drill rig with a large series, 2-3/4-inch by 3-7/8-inch core barrel in a 5-foot length in some holes and an "H" series wire line core barrel in others. Coring with air was unsuccessful because the moist, plastic clay cuttings could not be removed by this means. Water was used as the drilling fluid in all holes. The source of water was Otter Creek for Drill Hole 74-101 and the Tongue River for the remaining holes. The change in source was made to eliminate a potential contamination factor as the Otter Creek water was quite high in dissolved solids.

Bentonite was used in the drilling fluid in those zones in which lost circulation occurred. This was chiefly in the highly fractured and jointed coals. Contamination of drill cores either from use of highly mineralized water, additives such as bentonite, or from drill cuttings from strata of different chemical characteristics has been a much discussed subject. This potential is presently being investigated on cores obtained using drill fluids with induced high salt content and with additives such as bentonite. The analyses of these samples are being compared with those obtained by drilling with air and from the face of a highwall all within the same site. Preliminary field checks made by adding a flourescent dye (Flourescein) to the drill water and checking the obtained cores under an ultra-violet black light indicates that penetration by the drill fluid, if any, is less than 1 millimeter and can be easily removed in the preparation of the sample for laboratory testing.

Use of drilling tools larger than the standard exploratory sizes was dictated by (1) necessity to maximize core recovery, (2) provide sufficient sample for laboratory and greenhouse studies from zones as thin as 5 feet, and (3) to minimize the contamination potential. The 3-3/4-inch outside diameter hole also allowed placement of 2-inch pipe for ground-water level monitoring and sampling without additional reaming. Reaming was necessary where larger diameter wells for pump testing were desired.

The use of wire line drill tools was found to be faster than conventional drill tools below depths of 75 feet. To depths less than 75 feet, there did not appear to be any significant advantage. Most of the drilling was accomplished using bottom discharge bits set with tungsten carbide inserts. Both preset and field set bits were used. The chief advantage of field setting is better control of bit gage, both inside and outside, which in some of the softer rocks can be used to increase core recovery.

The recovered drill cores were placed in 5-foot-long core boxes which had been covered with a sheet of 4-mil polyethylene plastic which could be folded over the cores to prevent loss of moisture and a change of physical state until logging and sampling could be accomplished.

Details of the techniques, procedures, and standards used in the soils investigations are given in the section on soils.

Stratigraphy

The three-section study area is part of a peninsula-like bedrock high bounded on the north by Home Creek, on the south by Threemile Creek, and on the west by Otter Creek.

Two major topographic benches lie within the study area. The lowest bench is composed of resistant clinker and lies 40 to 180 feet above the creek flood plains. The second or highest bench lies 60 to 100 feet above the clinker and forms the topographic highs in the study area. The upper bench is controlled by a persistent sandstone ledge.

Incised drainages developed in the highest bench generally converge after reaching the resistant clinker area.

Three distinct zones were mapped in the study area as shown on the Geologic and Investigations Map, plate 5. These include deposits of alluvium, altered, and unaltered sediments of the Tongue River Member of the Fort Union Formation.

The Fort Union Formation of Paleocene Age underlies the entire area. It is divided into the Tulloch, Lebo, and Tongue River Members, but only the lower part of the Tongue River crops out or was penetrated by drilling in the study site. The Tulloch and Lebo Members lie at lower elevations and are not involved. The upper part of the Tongue River and younger sediments such as the Wasatch Formation of Eocene Age have been stripped away by Late Tertiary erosion. Recent deposits of alluvium mantle the Tongue River Member along Home, Threemile, and Otter Creeks. Brief descriptions of the Cenozoic stratigraphy follow:

Fort Union Formation (Paleocene Age):

Tulloch Member - consists of yellow-gray continental deposits of sandstone, shale, carbonaceous shale, and impure coal. It overlies the Late Cretaceous Hell Creek Formation. It varies in thickness from 275 to 500 feet in the Montana portion of the Powder River Basin.

Lebo Member - composed of drab, dark gray, continental deposits of shale which contrasts sharply with the light-colored overlying Tongue River and underlying Tulloch Members. Soil from the Lebo supports very little vegetation. A basal coalbed, "Big Dirty," separates the Lebo from the Tulloch Members. It underlies the study area but was not penetrated by drilling, and varies in thickness from 300 to 600 feet in the Montana portion of the Powder River Basin.

Tongue River Member - consists of pale-olive to yellowish-gray sandstone, siltstone, shale, carbonaceous shale and coal with thin lenticular, calcareous or siliceous cemented concretions, light to dark gray where unweathered, and fossiliferous in shales and siltstones. Poorly silicified, fragmented tree trunks are common in zones. These sediments were deposited in a continental environment which includes swamps conducive to the production of coalbeds up to 65 feet in thickness in the study area, and varies in thickness from 1,150 to 1,900 feet in the Montana portion of the Powder River Basin.

One striking feature in the Tongue River Member is the resistant clinker zones, locally called "scoria," that cap ridges or armor valley walls. The clinker, which is fused or baked rock, was produced by the burning of underlying coalbeds along their outcrops. The clinker, in places where the heat was sufficiently intense, has been fused to dark gray to black and in many respects resembles vesicular basalt. Near the outer edge of thermal metamorphism, the rock is disoriented, baked, and red to orange in color. Alteration of the overlying material is roughly proportional to the original thickness of coal that has burned. A coalbed 50 feet thick will produce clinker zones 100 to 200 feet thick. The clinker may be highly permeable, and locally supplies water to springs which surface near the base of the altered sediments. Growths of ponderosa pine are quite conspicuous in the clinkered areas. Boulders of clinker, erosional remnants of stratigraphically higher altered zones, are scattered along the upper benches in the study area.

Wasatch Formation (Eocene Age):

Consists of varicolored shale, siltstone, and sandstone. Locally conglomeratic, this formation overlies the Fort Union Formation, but does not occur in the study area. Further to the south, near the Montana-Wyoming border, about 500 feet of Wasatch rocks are found. Coal deposits of commercial grade occur in the Wasatch in Wyoming.

Isolated, undifferentiated, deposits of Pleistocene sand and gravel cap higher ridges in the region but are not involved in the study area with the possible exception of some terraces which were included with alluvial deposits on the Geologic and Investigations Map, plate 5.

Alluvium (Recent Age):

Consists of clay, silt, sand, and gravel that cover valley floors of major drainages. Gravels are generally composed of clinker and hard shale or sandstone fragments. These deposits fill the valley floors along Home, Threemile, and Otter Creeks. Soils investigations indicate that the alluvium is over 20 feet thick.

A near continuous band of thermally altered clinker produced by burning of the Knoblock coalbed along its outcrop lies between the alluvium and unaltered Tongue River sediments. This belt varies from several hundred feet on the south to over 5,000 feet in width on the north side of the study area. About 34 percent of the three-section area investigated is underlain by clinker up to 200 feet in thickness. A typical exposure of highly metamorphosed clinker is shown in photograph 2.

The contact between baked and unbaked rock trends diagonally from the northeast through the southwest corners of

Sections 26 and 34, T. 3 S., R. 45 E. Clinker also underlies most of the southwest quarter of Section 2, T. 4 S., R. 45 E. Exposures of altered and unaltered rock are shown in photograph 3. The lower bench on the left is clinker while the higher bench on the right is unaltered Tongue River sediments.

Some coal may remain beneath the clinker belt in the study area. Evidence supporting this is the unburned rock exposure surrounded by clinker in the east half of Section 33, T. 3 S., R. 45 E. Subsurface explorations and surface mining in other areas also indicate that lower sections of thick coalbeds have not always burned beneath clinkered areas. An extensive drilling program would be required to determine the amount of coal, if any, which underlies the thermally altered rock. For the purpose of this report, the contact between baked and unbaked rock was assumed to be vertical and that all coal underlying clinker has been burned.

The central and southeastern portions of the mapped area are underlain by unaltered Tongue River sediments. All subsurface investigations were conducted in this area. Drilling penetrated an alternating sequence of shale, siltstone, sandstone, and coal which included a 470-foot stratigraphic section lying between a horizon 320 feet above and 150 feet below the base of the Knoblock coalbed. Detailed descriptions of materials encountered in each drill hole are given on the geologic logs of drill holes, plates 9 through 17. In general, the shales vary from soft, plastic clayshale to moderately indurated claystone. The shale and siltstone zones break down readily and form slopes below sandstone ledges. The sandstones are fine grained and generally uncemented except as lenticular, concretionary masses of small lateral extent. Correlation of clastic sediments over short distances is difficult due to physical changes and variation in bedding thicknesses. The generalized geology of the three-section area is shown on the block diagram, plate 8.

Eleven persistent coal and/or carbonaceous shale beds were encountered in drilling. These are labeled A through K on the Geologic Sections X-Y and X-Z, plates 6 and 7. Five of these beds, A through E, were mapped at the surface and are shown on the Geologic and Investigations Map, plate 5.

The Knoblock (F) is the only coalbed in the study area considered economically feasible to surface mine. Subsurface explorations in the study area indicate that this bed averages 60.9 feet in thickness under overburden ranging from 30 to 220 feet thick.

The Flowers-Goodale coalbed which is 8 to 10 feet thick lies 105 to 120 feet below the Knoblock. Because of the thickness of overburden, surface mining of this bed in conjunction with the Knoblock is not considered economically feasible.

The remaining coal and/or carbonaceous beds (A through E, G through I, and J) are generally under 4 feet thick. None are of economic significance. Three beds, A through C, probably represent the upper, middle, and lower benches of the Sawyer coal zone. North of the study area, these beds thicken and converge into a potentially mineable coalbed.

Structure

Sediments in the study area are generally flat lying. However, minor folds or flexures were apparent at the surface. Two small anticlines and one syncline were mapped in Section 34, T. 3 S., R. 45 E. The two structures in the northeast quarter are possibly the result of collapse resulting from burning of the Knoblock coalbed beneath the adjacent clinker area. The east-west trending anticline in the southern part of Section 34 may be a depositional feature rather than deformation as the structure does not continue with depth. Photograph 4 is a panoramic view showing the anticlinal structure in the south half of Section 34.

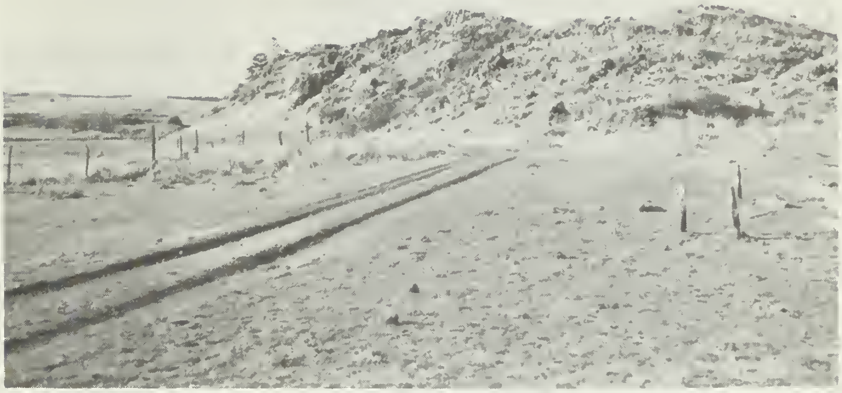
The most prominent flexure in the area is the north-northwest trending syncline in Sections 26, 35, and 36, T. 3 S., R. 45 E. This flexure terminates in flat lying sediments westward. Eastward the fold increases in magnitude and ends as a monoclinal fold or possible fault in the northwest corner of Section 36.

In places, sediments adjacent to the clinker areas dip towards the altered rock. Typical examples of this are the slide-like blocks in the northwest corner of Section 2, T. 4 S., R. 45 E. This collapse is attributed to the burning and reduction in volume of the underlying coal.

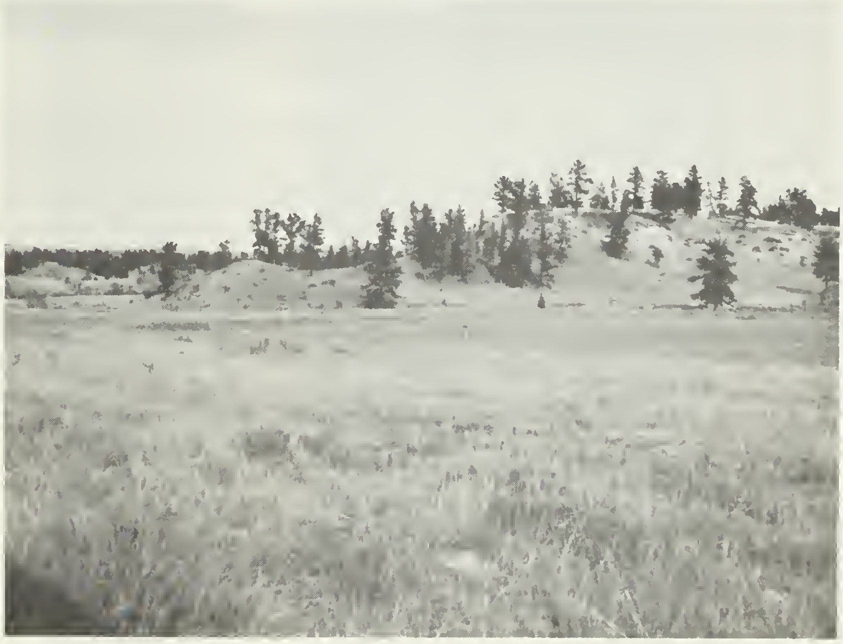
Structure contours representing elevations on top of the Knoblock coalbed are shown on the Overburden Thickness Map, plate 18. These contours were prepared using information obtained from the drilling done for this study and from the logs of holes drilled by the Montana Bureau of Mines and Geology. These contours show an approximate east-west trending syncline or sag exists near the center of the study area which is not surface reflected as the stratigraphically higher Sawyer coalbeds are nearly flay lying.

Geotechnical Properties

This section contains the results of selected physical properties tests of rocks from the Fort Union Formation in the Otter Creek study site. The rocks were obtained from Drill Holes 74-105 and 74-106, the locations of which are shown on plate 5. Testing was done at the drill hole site and also at the Engineering Geology Laboratory of the U.S. Geological Survey, Denver, Colorado. The purpose of this study is to gather and make public, data on the physical properties of the Fort Union Formation which relate to coal mining operations in this area, and to continue engineering geologic research in the Powder River Basin.

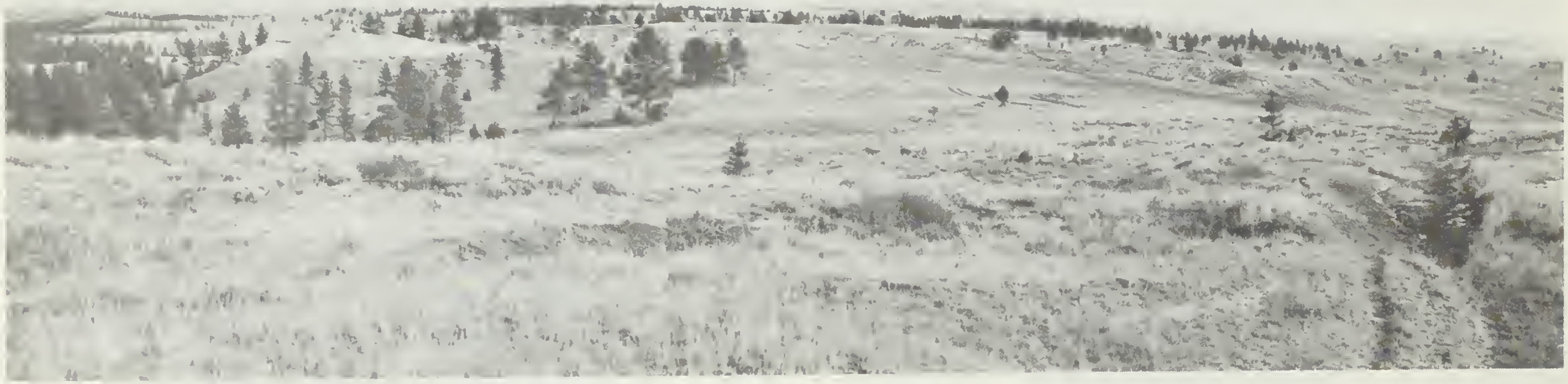


PHOTOGRAPH 2 - OTTER CREEK STUDY SITE - OTTER CREEK COAL FIELD. View looking northwest at highly metamorphosed clinker deposit in NE$\frac{1}{4}$ Section 4, T. 4 S., R. 45 E. Otter Creek flood plain is shown in background on left side of photograph.
U.S. Bureau of Reclamation Photograph P-1305-600-1(NA) 11/15/74



PHOTOGRAPH 3 - OTTER CREEK STUDY SITE - OTTER CREEK COAL FIELD. View looking northeast at contact between baked and unbaked rock. Photograph taken from trail about 800 feet north of center Section 26, T. 3 S., R. 45 E. Lower ledge on left is clinker. Higher ridge on right is unaltered Tongue River sediments. Home Creek is shown in background on left side of picture.
U. S. Bureau of Reclamation Photograph P-1305-600-2(NA) 11/15/74

Photograph 4



PHOTOGRAPH 4 - OTTER CREEK STUDY SITE - OTTER CREEK COAL FIELD. Panoramic view looking east at typical terrain in study area. Photograph taken from point 500 feet southeast of Drill Hole 74-101. The Sawyer "C" coal bed lies just below the light colored resistant ledge shown trending across center of picture. Photograph taken along the approximate axis of an anticlinal structure. The axis of this structure forms the drainage divide between Home and Threemile Creeks.

U. S. Bureau of Reclamation Photograph P-1305-600-3(NA) 11/15/74

Testing of the rock samples has followed ASTM procedures wherever possible. The ASTM test designations are listed in the explanatory notes. The other tests that are not accepted as ASTM standards, are included in this report as research and experimental information.

Engineering Geology

Approximately 400 tests were performed on the 72 rock samples that were taken for study. The results of these tests indicate, but do not prove, engineering geologic problems associated with the in-place material and the disturbed material.

Compressive and tensile index tests performed on the rock samples generally have low values, with only a few exceptions. These data, and the physical properties data; Atterberg Limits, Gradation (grain-size distribution), suggest careful design in slopes, open mine faces and open pit floors. Disturbed overburden material (spoil banks and piles), should have slopes not greater than 1 to 4, with berms of 50 to 100 feet in width designed on the slope surface. Ponding of water on the surface of the disturbed material is not recommended, unless the ponded area is mechanically compacted and sealed to prevent excess water from permeating and saturating the disturbed material. Overburden should be removed at least one cut width (100 ft) away from the working face of an open-pit mine. The floors of open-pit mines will need adequate drainage to keep the moisture content of the floor material below the plastic limit. The results of the tests are shown on plate 19.

Weathering Tests

Weathering tests were conducted on 17 overburden core samples from the Otter Creek Site. The purpose of these tests was to determine which materials would weather (break down) sufficiently to allow for their possible use as topsoil in revegetation of strip-mined areas.

Duplicate specimens from each core depth were selected for either freeze-thaw or wet-dry tests. The freeze-thaw cycle consisted of the following:

1. Wetting-thawing cycle: 8 hours at 75° F, 100 percent relative humidity.

2. Freezing cycle: 16 hours (64 hours on weekends) at -10° F.

The wet-dry tests (one cycle) consisted of the following:

1. Wetting cycle: 8 hours at 75° F, 100 percent relative humidity.

2. Drying cycle: 16 hours (64 hours on weekends) at 100° F, 10 percent relative humidity.

Where possible, core specimens about 2 inches in diameter by 2 inches high were used. In other cases, several pieces of core samples totaling the approximate same size were used. For testing and handling, the core specimens were placed in 1-pint wax cardboard containers.

Tests were started on January 30, 1975, and 30 weathering cycles were completed on March 14, 1975. During the test period, the specimens were visually examined several times a week to determine what changes had occurred.

On completion of the testing, a percent breakdown value (% BD) was determined for a number of the specimens. This value was obtained as follows:

$$\% \text{ BD} = \frac{\text{TW} - \text{IW}}{\text{TW}} \times 100$$

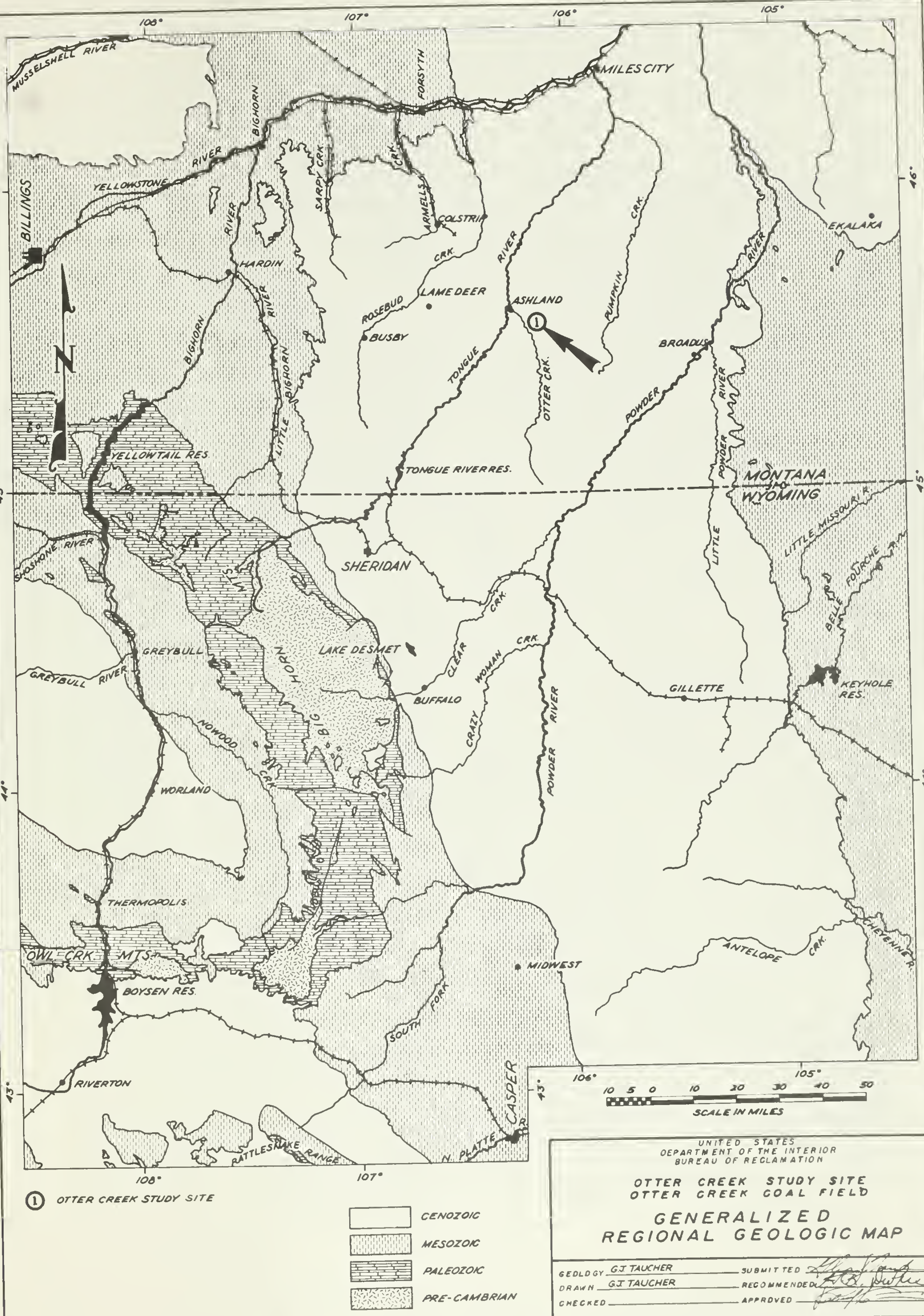
Where

TW = Total sample weight.
IW = Weight of original sample remaining intact after testing.

No percent BD was determined for samples which exhibited swelling characteristics.

The results of the weathering tests indicated that the freezing-thawing condition generally caused more weathering or breakdown than wetting-drying. This was evident by both visual examination and gradation analyses conducted on several samples after testing.

Of the 17 samples tested, only four (24%) exhibited sufficient breakdown to attain the texture required for topsoil, that is, 30 percent by weight of the soil passing the No. 10 screen. In the field, however, these materials, primarily shales, will probably weather at different rates, and this will require various methods of handling, storing, and processing before they are suitable for use as topsoil in revegetation.



UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

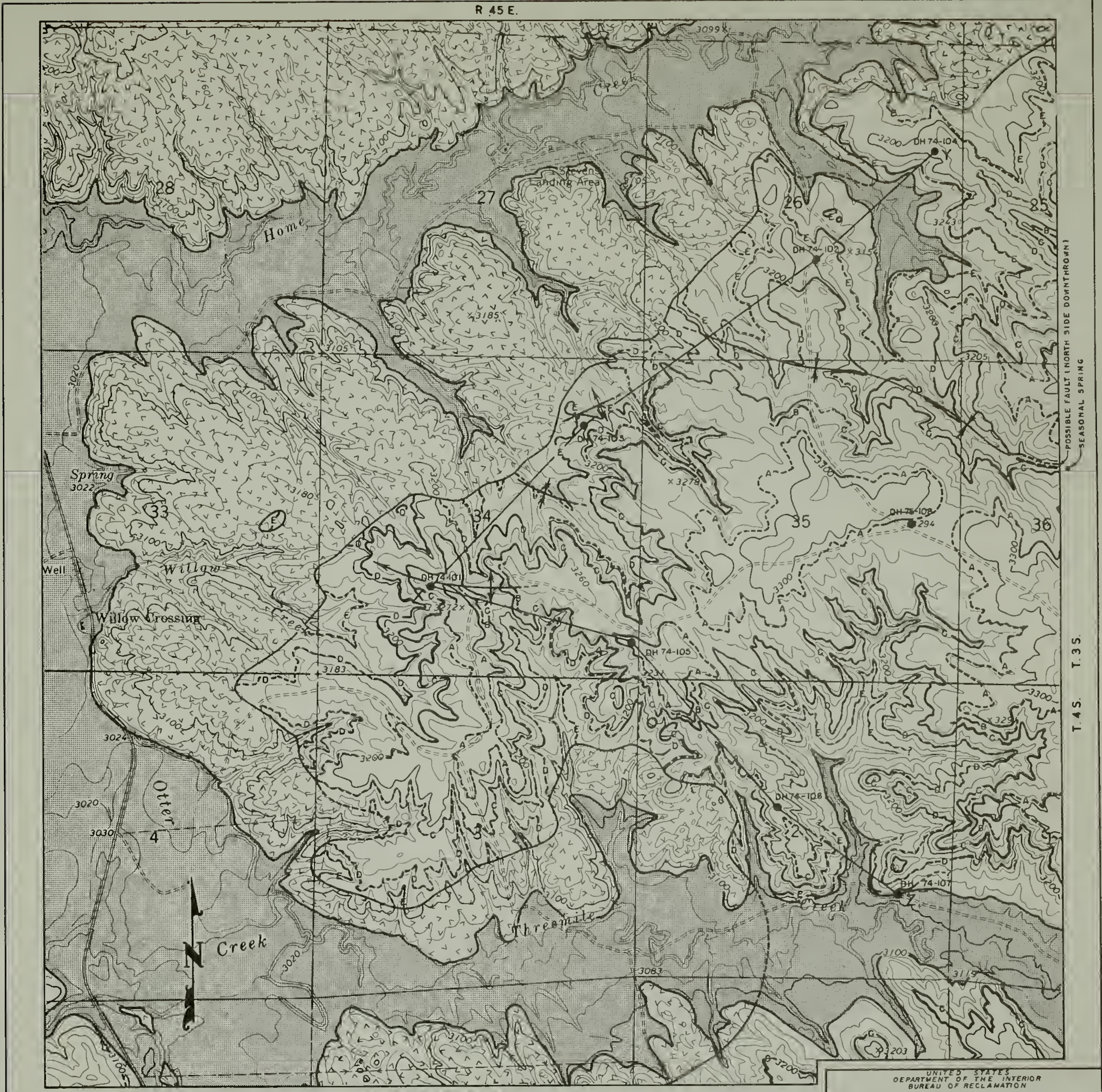
OTTER CREEK STUDY SITE
OTTER CREEK COAL FIELD

GENERALIZED
REGIONAL GEOLOGIC MAP

GEOLOGY G.J. TAUCHER SUBMITTED
DRAWN G.J. TAUCHER RECOMMENDED
CHECKED APPROVED

BILLINGS, MONTANA FEBRUARY 1975 1305-600-2

PLATE 5



L E G E N D

RECENT	▨	ALLUVIUM-SAND, SILT & CLAY. UP TO 50FT THICK.
PALEOCENE	☐	FT. UNION FM. (TONGUE RIVER MEMBER) SANDSTONE, SILTSTONE & SHALE. CONTAINS COAL BEDS UP TO 65-FT. IN THICKNESS.
	☐	CLINKER-BAKED SANDSTONE, SILTSTONE & SHALE OF THE FT UNION FM. PRODUCED BY BURNING OF THE KNOBLOCK COAL BED. UP TO 200-FT THICK.
	X-Y-Z	LIMITS OF GEOLOGIC SECTIONS

●	USBR DRILL HOLE (DH 74-101 THRU 107 & 75-108)
―	GEOLOGIC CONTACT-DASHED WHERE INFERRED.
—A—	A-E COAL AND/OR CARBONACEOUS SHALE BEDS UP TO 4-FT THICK-DASHED WHERE INFERRED
	ANTICLINE
	SYNCLINE

1000 0 1000 2000
SCALE OF FEET

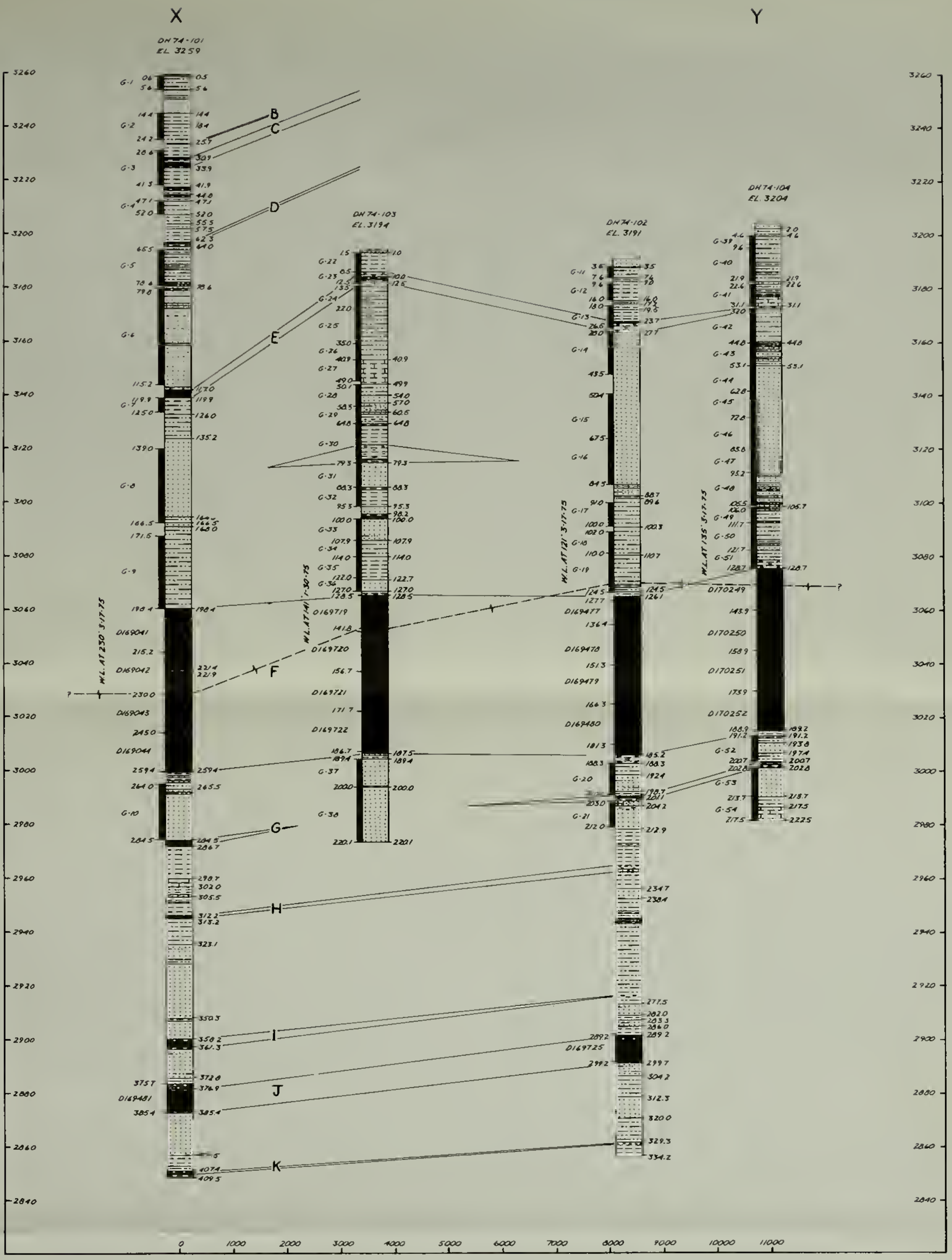
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

OTTER CREEK STUDY SITE
OTTER CREEK COAL FIELD

GEOLOGIC AND INVESTIGATIONS MAP

GEOLOGY G J TAUCHER SUBMITTED
DRAWN G J TAUCHER RECOMMENDED
CHECKED APPROVED

BILLINGS, MONTANA FEBRUARY 1975 1305-600-3



LEGEND

▨ TOPSOIL

SANDSTONE

SILTSTONE

SHALE

CALCAREOUS SHALE, MARL OR LIMESTONE

■ COAL

CARBONACEOUS SHALE, SILTSTONE OR SANDSTONE

65.5 G-5 78.1 SOILS ANALYSIS SAMPLE SEE PLATE 26

B THRU K COAL AND/OR CARBONACEOUS SHALE BEDS
B-C = SAWYER COAL BEDS
F = KNOBLOCK COAL BED
J = FLOWERS-GOODALE COAL BED

215.3 D169042 230.0 COAL ANALYSIS SAMPLE (U.S.B.M.) SEE TABLE 4

GROUND WATER TABLE

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

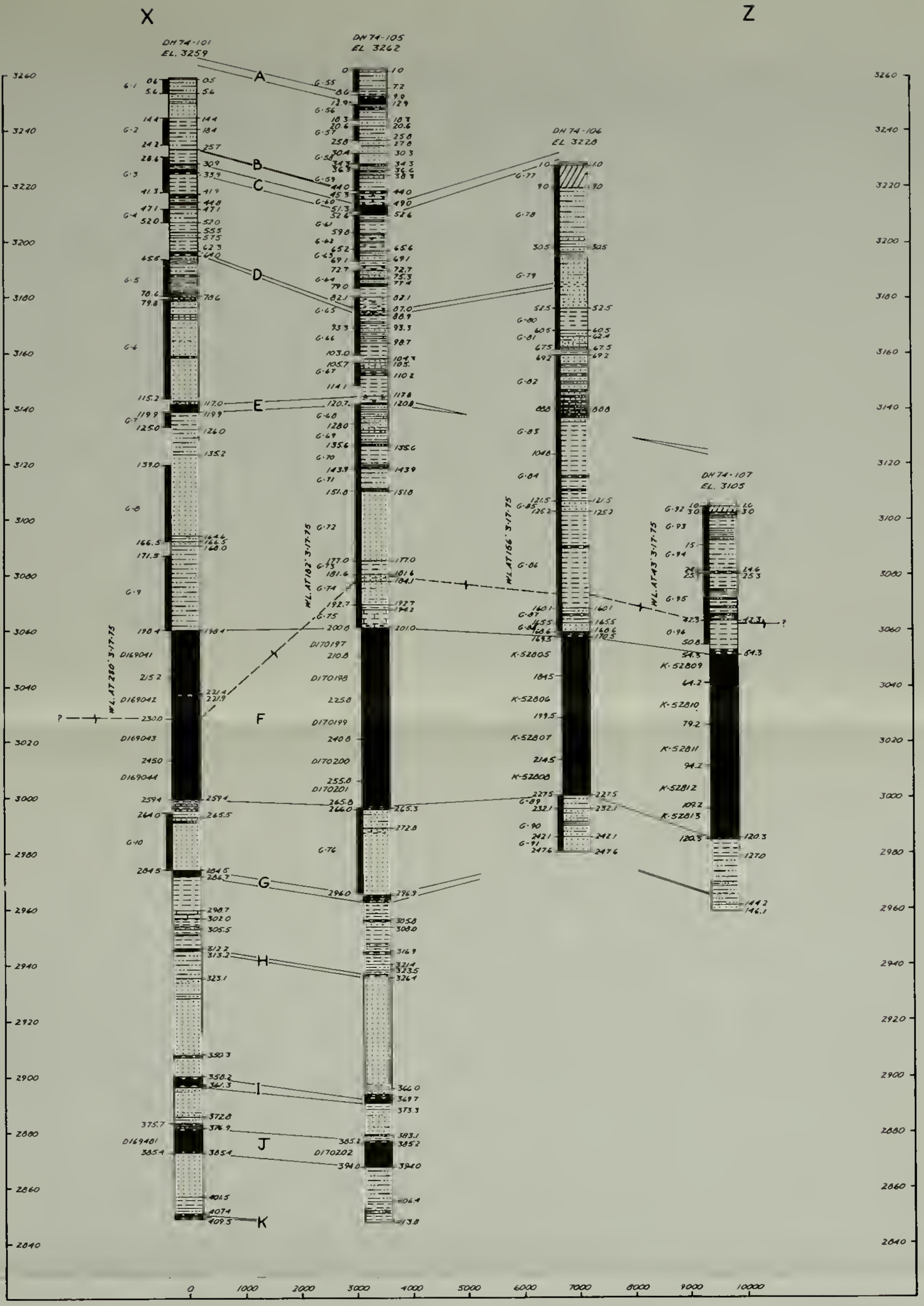
OTTER CREEK STUDY SITE
OTTER CREEK COAL FIELD

GEOLOGIC SECTION X-Y

GEOLOGY G.J. TAUCHER SUBMITTED
DRAWN G.J. TAUCHER RECOMMENDED
CHECKED APPROVED

BILLINGS, MONTANA FEBRUARY 1976 1305-600-4

PLATE 6



LEGEND

- ▨ TOPSOIL
- SANDSTONE
- SILTSTONE
- SHALE
- CALCAREOUS SHALE, MARL OR LIMESTONE
- ■ COAL
- CARBONACEOUS SHALE, SILTSTONE OR SANDSTONE

65.5 – G-5 – 70.1 SOILS ANALYSIS SAMPLE SEE PLATE 26

A THRU K COAL AND/OR CARBONACEOUS SHALE BEDS
A - C = SAWYER COAL BEDS
F = KNOBLOCK COAL BED
J = FLOWERS-GOODALE COAL BED

215.2 – D169042 – 230.0 COAL ANALYSIS SAMPLE (U.S.B.M.) SEE TABLE 4

—+— GROUND WATER TABLE

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

OTTER CREEK STUDY SITE
OTTER CREEK COAL FIELD

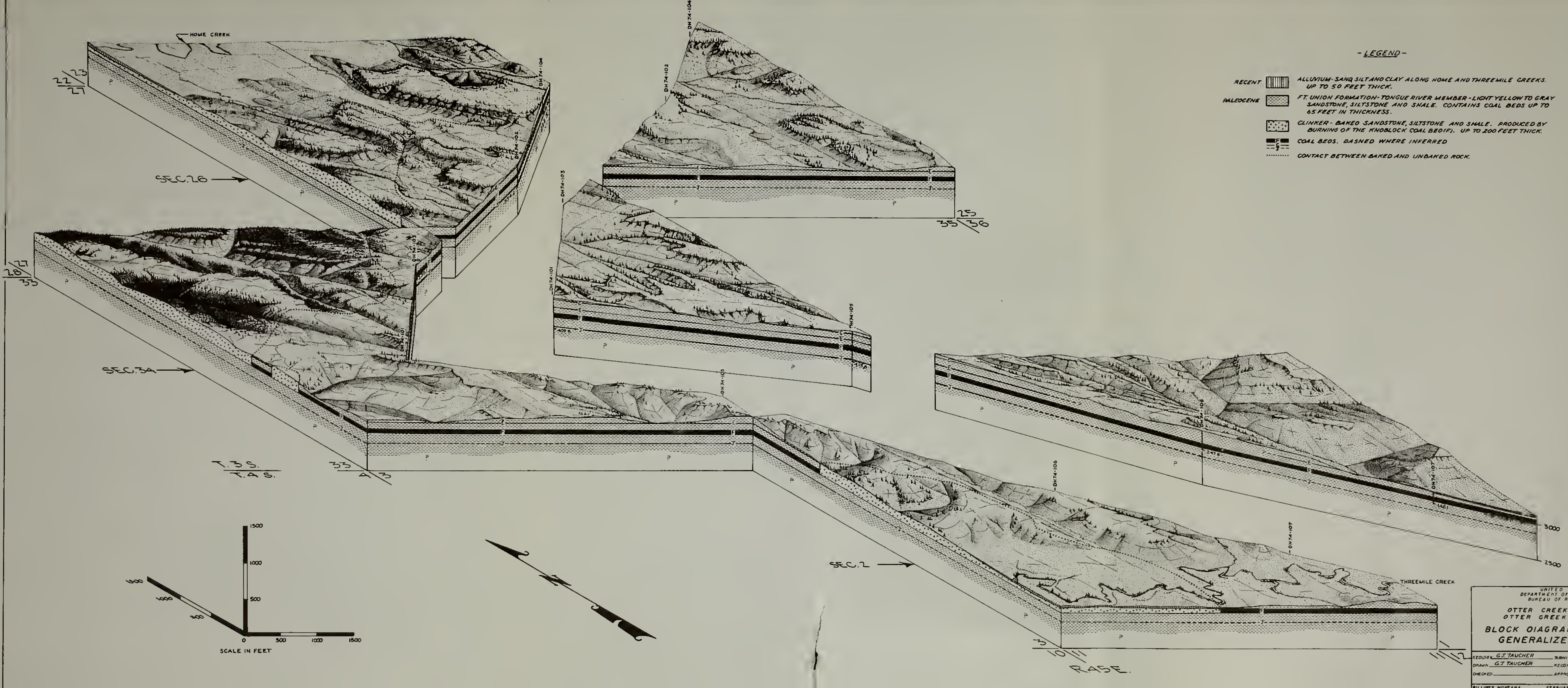
GEOLOGIC SECTION X - Z

GEOLOGY G.J. TAUCHER SUBMITTED
DRAWN G.J. TAUCHER RECOMMENDED
CHECKED APPROVED

BILLINGS, MONTANA FEBRUARY 1975 1305-600-5

PLATE 7

PLATE 8



- LEGEND -

RECENT	▥	ALLUVIUM - SAND, SILT AND CLAY ALONG HOME AND THREEMILE CREEKS. UP TO 50 FEET THICK.
PALEOCENE	▤	FT. UNION FORMATION - TONGUE RIVER MEMBER - LIGHT YELLOW TO GRAY SANDSTONE, SILTSTONE AND SHALE. CONTAINS COAL BEDS UP TO 65 FEET IN THICKNESS.
	▨	CLINKER - BAKED SANDSTONE, SILTSTONE AND SHALE. PRODUCED BY BURNING OF THE KNOBLOCK COAL BED(F). UP TO 200 FEET THICK.
	▬ F	COAL BEDS. DASHED WHERE INFERRED
	······	CONTACT BETWEEN BAKED AND UNBAKED ROCK.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

OTTER CREEK STUDY SITE
OTTER CREEK COAL FIELD

BLOCK DIAGRAM SHOWING THE GENERALIZED GEOLOGY

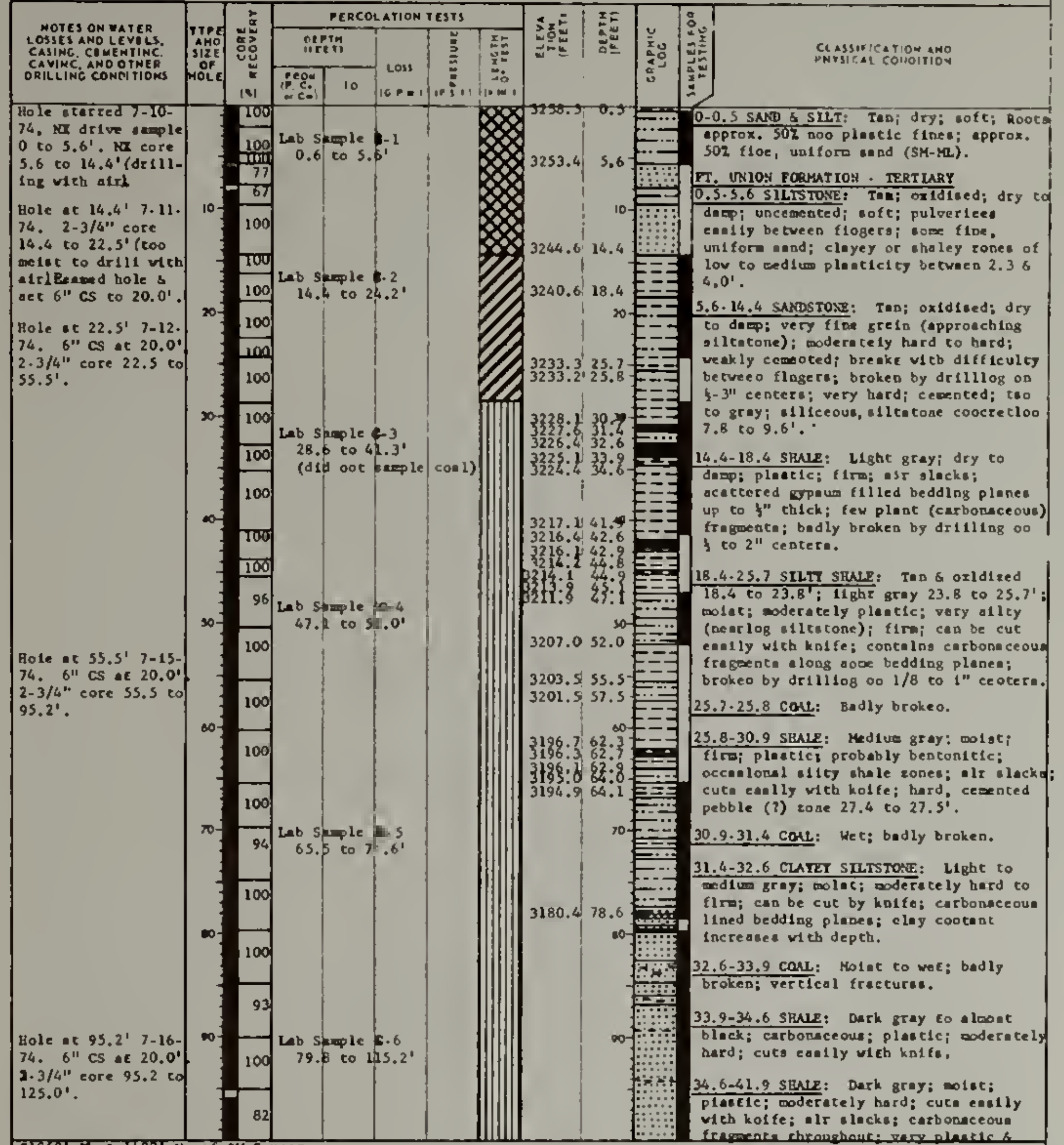
GEOLOGY G.J. TAUCHER SUBMITTED
DRAWN G.J. TAUCHER RECOMMENDED
CHECKED APPROVED

BILLINGS, MONTANA FEBRUARY 1975 1305-600-6

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 7

FEATURE Otter Creek Study Site PROJECT STATE Montana
HOLE NO DH 74-101 LOCATION * COORDS. N. E. GROUND ELEV Altimeter 3259 DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 7-10-74 FINISHED 8-9-74 DEPTH OF OVERBURDEN 0.5' TOTAL DEPTH 409.5 BEARING –
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 229.6' 8-6-74 LOGGED BY Taucher LOG REVIEWED BY



NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

Hole started 7-10-74, NX drive sample 0 to 5.6'. NX core 5.6 to 14.4' (drilling with air).

Hole at 14.4' 7-11-74. 2-3/4" core 14.4 to 22.5' (too moist to drill with air). Reamed hole & set 6" CS to 20.0'.

Hole at 22.5' 7-12-74. 6" CS at 20.0'. 2-3/4" core 22.5 to 55.5'.

Hole at 55.5' 7-15-74. 6" CS at 20.0'. 2-3/4" core 55.5 to 95.2'.

Hole at 95.2' 7-16-74. 6" CS at 20.0'. 2-3/4" core 95.2 to 125.0'.

*1850' E. & 1480' N. of SW Corner Sec. 34, T. 3 S., R. 45 E.

PERCOLATION TESTS

Lab Sample G-1 0.6 to 5.6'

Lab Sample G-2 14.4 to 24.2'

Lab Sample G-3 28.6 to 41.3' (did not sample coal)

Lab Sample G-4 47.1 to 51.0'

Lab Sample G-5 65.5 to 7 .6'

Lab Sample G-6 79.8 to 115.2'

CLASSIFICATION AND PHYSICAL CONDITION

0-0.5 SAND & SILT: Tan; dry; soft; Roots approx. 50% non plastic fines; approx. 50% fine, uniform sand (SM-ML).

FT. UNION FORMATION - TERTIARY

0.5-5.6 SILTSTONE: Tan; oxidized; dry to damp; uncemented; soft; pulverizes easily between fingers; some fine, uniform sand; clayey or shaley zones of low to medium plasticity between 2.3 & 4.0'.

5.6-14.4 SANDSTONE: Tan; oxidized; dry to damp; very fine grain (approaching siltstone); moderately hard to hard; weakly cemented; breaks with difficulty between fingers; broken by drilling on ½-3" centers; very hard; cemented; tan to gray; siliceous, siltstone concretion 7.8 to 9.6'.

14.4-18.4 SHALE: Light gray; dry to damp; plastic; firm; air slacks; scattered gypsum filled bedding planes up to ½" thick; few plant (carbonaceous) fragments; badly broken by drilling on ½ to 2" centers.

18.4-25.7 SILTY SHALE: Tan & oxidized 18.4 to 23.8'; light gray 23.8 to 25.7'; moist; moderately plastic; very silty (nearing siltstone); firm; can be cut easily with knife; contains carbonaceous fragments along some bedding planes; broken by drilling on 1/8 to 1" centers.

25.7-25.8 COAL: Badly broken.

25.8-30.9 SHALE: Medium gray; moist; firm; plastic; probably bentonitic; occasional silty shale zones; air slacks; cuts easily with knife; hard, cemented pebble (?) zone 27.4 to 27.5'.

30.9-31.4 COAL: Wet; badly broken.

31.4-32.6 CLAYEY SILTSTONE: Light to medium gray; moist; moderately hard to firm; can be cut by knife; carbonaceous lined bedding planes; clay content increases with depth.

32.6-33.9 COAL: Moist to wet; badly broken; vertical fractures.

33.9-34.6 SHALE: Dark gray to almost black; carbonaceous; plastic; moderately hard; cuts easily with knife.

34.6-41.9 SHALE: Dark gray; moist; plastic; moderately hard; cuts easily with knife; air slacks; carbonaceous fragments throughout; very plastic &

EXPLANATION

CORE LOSS
CORE RECOVERY

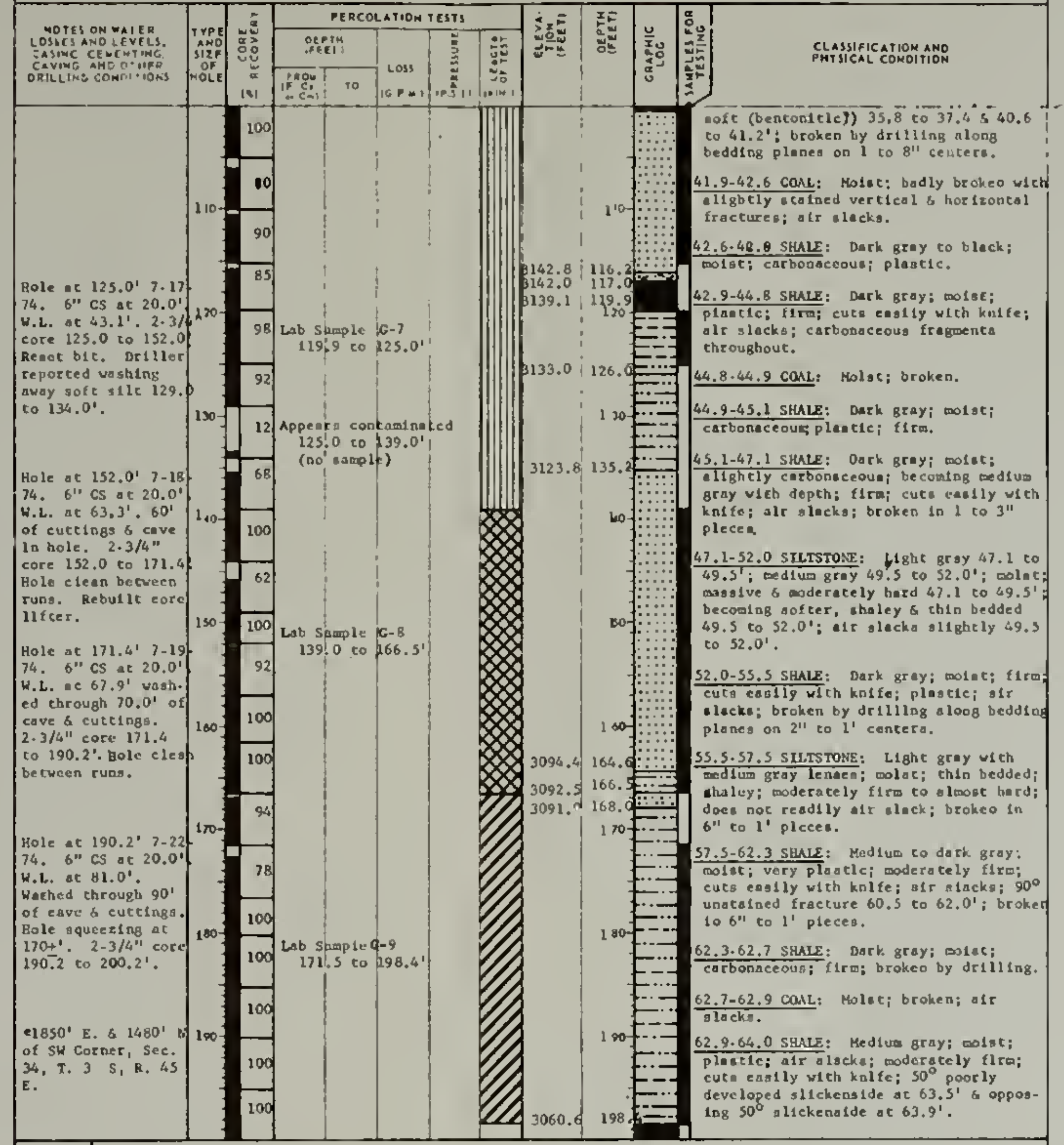
Type of hole .... D = Diamond, H = [illegible], S = Shot, C = Churn
Hole sealed .... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Otter Creek Study Site PROJECT STATE Mont. SHEET 1 OF 7 HOLE NO DH74-101

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 7

FEATURE Otter Creek Study Site PROJECT STATE Montana
HOLE NO DH 74-101 LOCATION * COORDS N E GROUND ELEV Altimeter 3259 DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 7-10-74 FINISHED 8-9-74 DEPTH OF OVERBURDEN 0.5' TOTAL DEPTH 409.5 BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 229.6' 8-6-74 LOGGED BY Taucher LOG REVIEWED BY



NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

Hole at 125.0' 7-17-74. 6" CS at 20.0'. W.L. at 43.1'. 2-3/4" core 125.0 to 152.0'. Reset bit. Driller reported washing away soft silt 129.0 to 134.0'.

Hole at 152.0' 7-18-74. 6" CS at 20.0'. W.L. at 63.3'. 60' of cuttings & cave in hole. 2-3/4" core 152.0 to 171.4'. Hole clean between runs. Rebuilt core lifter.

Hole at 171.4' 7-19-74. 6" CS at 20.0'. W.L. at 67.9' washed through 70.0' of cave & cuttings. 2-3/4" core 171.4 to 190.2'. Hole clean between runs.

Hole at 190.2' 7-22-74. 6" CS at 20.0'. W.L. at 81.0'. Washed through 90' of cave & cuttings. Hole squeezing at 170+'. 2-3/4" core 190.2 to 200.2'.

*1850' E. & 1480' N. of SW Corner, Sec. 34, T. 3 S, R. 45 E.

PERCOLATION TESTS

Lab Sample G-7 119.9 to 125.0'

Appears contaminated 125.0 to 139.0' (no sample)

Lab Sample G-8 139.0 to 166.5'

Lab Sample G-9 171.5 to 198.4'

CLASSIFICATION AND PHYSICAL CONDITION

soft (bentonitic?) 35.8 to 37.4 & 40.6 to 41.2'; broken by drilling along bedding planes on 1 to 8" centers.

41.9-42.6 COAL: Moist; badly broken with slightly stained vertical & horizontal fractures; air slacks.

42.6-42.9 SHALE: Dark gray to black; moist; carbonaceous; plastic.

42.9-44.8 SHALE: Dark gray; moist; plastic; firm; cuts easily with knife; air slacks; carbonaceous fragments throughout.

44.8-44.9 COAL: Moist; broken.

44.9-45.1 SHALE: Dark gray; moist; carbonaceous; plastic; firm.

45.1-47.1 SHALE: Dark gray; moist; slightly carbonaceous; becoming medium gray with depth; firm; cuts easily with knife; air slacks; broken in 1 to 3" pieces.

47.1-52.0 SILTSTONE: Light gray 47.1 to 49.5'; medium gray 49.5 to 52.0'; moist; massive & moderately hard 47.1 to 49.5'; becoming softer, shaley & thin bedded 49.5 to 52.0'; air slacks slightly 49.5 to 52.0'.

52.0-55.5 SHALE: Dark gray; moist; firm; cuts easily with knife; plastic; air slacks; broken by drilling along bedding planes on 2" to 1' centers.

55.5-57.5 SILTSTONE: Light gray with medium gray lenses; moist; thin bedded; shaley; moderately firm to almost hard; does not readily air slack; broken in 6" to 1' pieces.

57.5-62.3 SHALE: Medium to dark gray; moist; very plastic; moderately firm; cuts easily with knife; air slacks; 90° unstained fracture 60.5 to 62.0'; broken in 6" to 1' pieces.

62.3-62.7 SHALE: Dark gray; moist; carbonaceous; firm; broken by drilling.

62.7-62.9 COAL: Moist; broken; air slacks.

62.9-64.0 SHALE: Medium gray; moist; plastic; air slacks; moderately firm; cuts easily with knife; 50° poorly developed slickenside at 63.5' & opposing 50° slickenside at 63.9'.

EXPLANATION

CORE LOSS
CORE RECOVERY

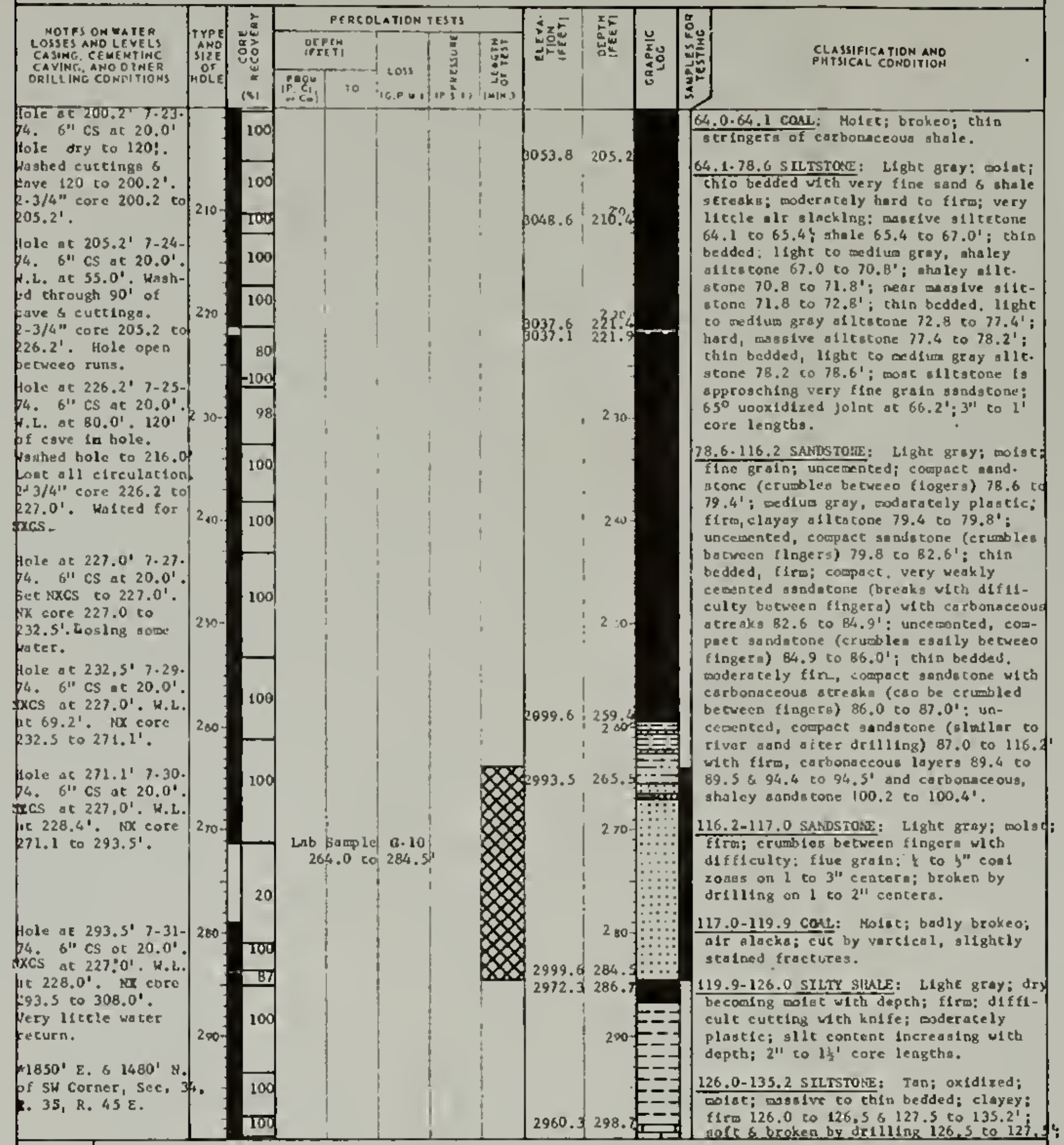
Type of hole .... D = Diamond, H = [illegible], S = Shot, C = Churn
Hole sealed .... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Otter Creek Study Site PROJECT STATE Mont. SHEET 2 OF 7 HOLE NO DH 74-101

GEOLOGIC LOG OF DRILL HOLE

SHEET 3 OF 7

FEATURE Otter Creek Study Site PROJECT STATE Montana
HOLE NO DH 74-101 LOCATION * COORDS N. E. GROUND ELEV Altimeter 3259 DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 7-10-74 FINISHED 8-9-74 DEPTH OF OVERBURDEN 0.5' TOTAL DEPTH 409.5 BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 229.6' 8-6-74 LOGGED BY Taucher LOG REVIEWED BY



NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

Hole at 200.2' 7-23-74. 6" CS at 20.0' Hole dry to 120'. Washed cuttings & cave 120 to 200.2'. 2-3/4" core 200.2 to 205.2'.

Hole at 205.2' 7-24-74. 6" CS at 20.0'. W.L. at 55.0'. Washed through 90' of cave & cuttings. 2-3/4" core 205.2 to 226.2'. Hole open between runs.

Hole at 226.2' 7-25-74. 6" CS at 20.0'. W.L. at 80.0'. 120' of cave in hole. Washed hole to 216.0' Lost all circulation. 2-3/4" core 226.2 to 227.0'. Waited for NXCS.

Hole at 227.0' 7-27-74. 6" CS at 20.0'. Set NXCS to 227.0'. NX core 227.0 to 232.5'. Losing some water.

Hole at 232.5' 7-29-74. 6" CS at 20.0'. NXCS at 227.0'. W.L. at 69.2'. NX core 232.5 to 271.1'.

Hole at 271.1' 7-30-74. 6" CS at 20.0'. NXCS at 227.0'. W.L. at 228.4'. NX core 271.1 to 293.5'.

Hole at 293.5' 7-31-74. 6" CS at 20.0'. NXCS at 227.0'. W.L. at 228.0'. NX core 293.5 to 308.0'. Very little water return.

*1850' E. & 1480' N. of SW Corner, Sec. 34, T. 3S, R. 45 E.

PERCOLATION TESTS

Lab Sample G-10 264.0 to 284.5'

CLASSIFICATION AND PHYSICAL CONDITION

64.0-64.1 COAL: Moist; broken; thin stringers of carbonaceous shale.

64.1-78.6 SILTSTONE: Light gray; moist; thin bedded with very fine sand & shale streaks; moderately hard to firm; very little air slacking; massive siltstone 64.1 to 65.4'; shale 65.4 to 67.0'; thin bedded; light to medium gray, shaley siltstone 67.0 to 70.8'; shaley siltstone 70.8 to 71.8'; near massive siltstone 71.8 to 72.8'; thin bedded, light to medium gray siltstone 72.8 to 77.4'; hard, massive siltstone 77.4 to 78.2'; thin bedded, light to medium gray siltstone 78.2 to 78.6'; most siltstone is approaching very fine grain sandstone; 65° unoxidized joint at 66.2'; 3" to 1' core lengths.

78.6-116.2 SANDSTONE: Light gray; moist; fine grain; uncemented; compact sandstone (crumbles between fingers) 78.6 to 79.4'; medium gray, moderately plastic; firm, clayey siltstone 79.4 to 79.8'; uncemented, compact sandstone (crumbles between fingers) 79.8 to 82.6'; thin bedded, firm; compact, very weakly cemented sandstone (breaks with difficulty between fingers) with carbonaceous streaks 82.6 to 84.9'; uncemented, compact sandstone (crumbles easily between fingers) 84.9 to 86.0'; thin bedded, moderately firm, compact sandstone with carbonaceous streaks (can be crumbled between fingers) 86.0 to 87.0'; uncemented, compact sandstone (similar to river sand after drilling) 87.0 to 116.2' with firm, carbonaceous layers 89.4 to 89.5 & 94.4 to 94.5' and carbonaceous, shaley sandstone 100.2 to 100.4'.

116.2-117.0 SANDSTONE: Light gray; moist; firm; crumbles between fingers with difficulty; fine grain; ¼ to ½" coal zones on 1 to 3" centers; broken by drilling on 1 to 2" centers.

117.0-119.9 COAL: Moist; badly broken; air slacks; cut by vertical, slightly stained fractures.

119.9-126.0 SILTY SHALE: Light gray; dry becoming moist with depth; firm; difficult cutting with knife; moderately plastic; silt content increasing with depth; 2" to 1½' core lengths.

126.0-135.2 SILTSTONE: Tan; oxidized; moist; massive to thin bedded; clayey; firm 126.0 to 126.5 & 127.5 to 135.2'; soft & broken by drilling 126.5 to 127.5';

EXPLANATION

CORE LOSS
CORE RECOVERY

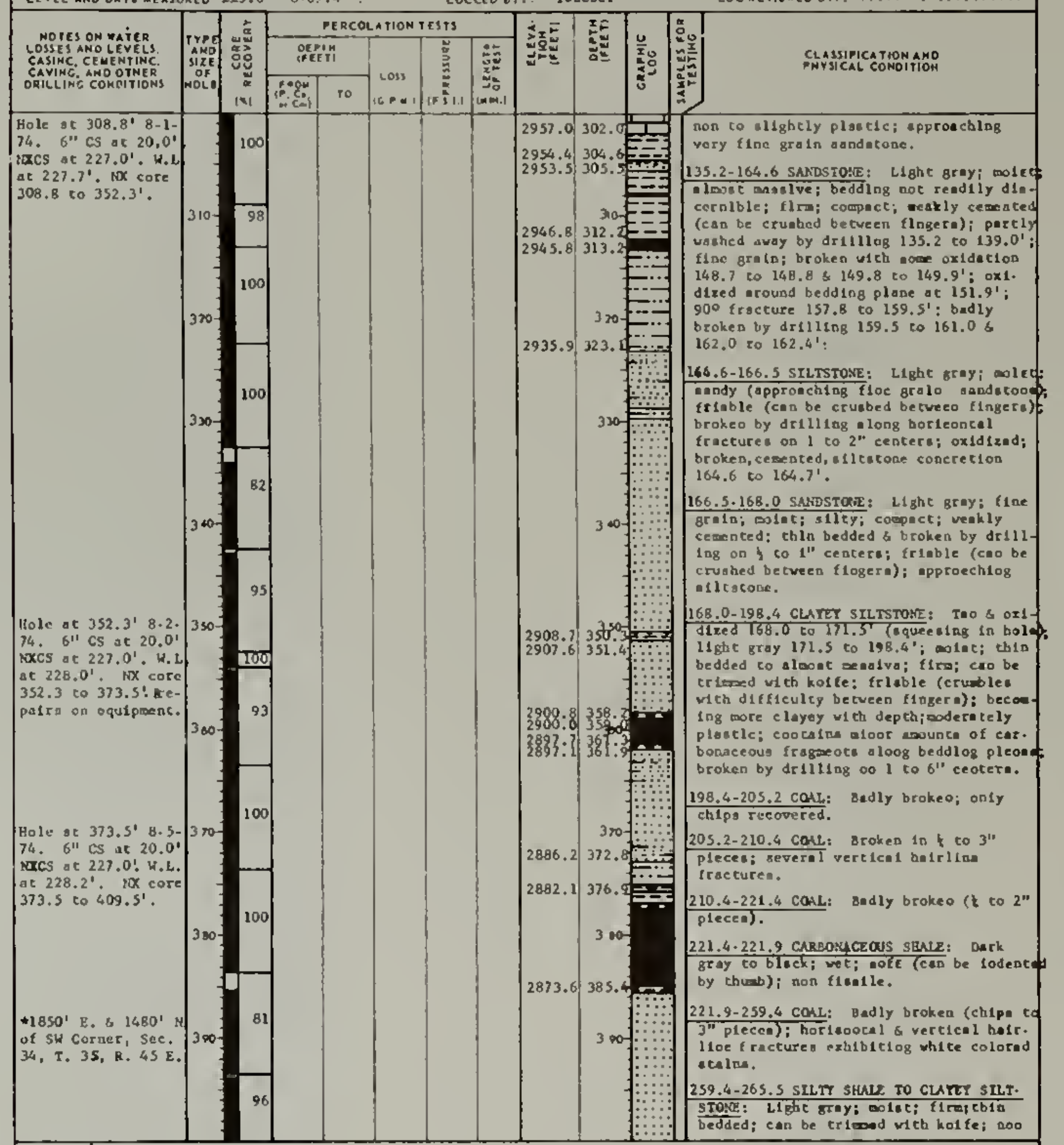
Type of hole .... D = Diamond, H = [illegible], S = Shot, C = Churn
Hole sealed .... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Otter Creek Study Site PROJECT STATE Mont. SHEET 3 OF 7 HOLE NO. DH74-101

GEOLOGIC LOG OF DRILL HOLE

SHEET 4 OF 7

FEATURE Otter Creek Study Site PROJECT STATE Montana
HOLE NO DH 74-101 LOCATION * COORDS. N. E. GROUND ELEV. Altimeter 3259 DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 7-10-74 FINISHED 8-9-74 DEPTH OF OVERBURDEN 0.5' TOTAL DEPTH 409.5 BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 229.6' 8-6-74 LOGGED BY Taucher LOG REVIEWED BY



NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

Hole at 308.8' 8-1-74. 6" CS at 20.0'. NXCS at 227.0'. W.L. at 227.7'. NX core 308.8 to 352.3'.

Hole at 352.3' 8-2-74. 6" CS at 20.0' NXCS at 227.0'. W.L. at 228.0'. NX core 352.3 to 373.5'. Repairs on equipment.

Hole at 373.5' 8-5-74. 6" CS at 20.0' NXCS at 227.0'. W.L. at 228.2'. NX core 373.5 to 409.5'.

*1850' E. & 1480' N. of SW Corner, Sec. 34, T. 3S, R. 45 E.

CLASSIFICATION AND PHYSICAL CONDITION

non to slightly plastic; approaching very fine grain sandstone.

135.2-164.6 SANDSTONE: Light gray; moist; almost massive; bedding not readily discernible; firm; compact; weakly cemented (can be crushed between fingers); partly washed away by drilling 135.2 to 139.0'; fine grain; broken with some oxidation 148.7 to 148.8 & 149.8 to 149.9'; oxidized around bedding plane at 151.9'; 90° fracture 157.8 to 159.5'; badly broken by drilling 159.5 to 161.0 & 162.0 to 162.4':

164.6-166.5 SILTSTONE: Light gray; moist; sandy (approaching fine grain sandstone); friable (can be crushed between fingers); broken by drilling along horizontal fractures on 1 to 2" centers; oxidized; broken, cemented, siltstone concretion 164.6 to 164.7'.

166.5-168.0 SANDSTONE: Light gray; fine grain; moist; silty; compact; weakly cemented; thin bedded & broken by drilling on ½ to 1" centers; friable (can be crushed between fingers); approaching siltstone.

168.0-198.4 CLAYEY SILTSTONE: Tan & oxidized 168.0 to 171.5' (squeezing in hole); light gray 171.5 to 198.4'; moist; thin bedded to almost massive; firm; can be trimmed with knife; friable (crumbles with difficulty between fingers); becoming more clayey with depth; moderately plastic; contains minor amounts of carbonaceous fragments along bedding planes; broken by drilling on 1 to 6" centers.

198.4-205.2 COAL: Badly broken; only chips recovered.

205.2-210.4 COAL: Broken in ¼ to 3" pieces; several vertical hairline fractures.

210.4-221.4 COAL: Badly broken (¼ to 2" pieces).

221.4-221.9 CARBONACEOUS SHALE: Dark gray to black; wet; soft (can be indented by thumb); non fissile.

221.9-259.4 COAL: Badly broken (chips to 3" pieces); horizontal & vertical hairline fractures exhibiting white colored stains.

259.4-265.5 SILTY SHALE TO CLAYEY SILTSTONE: Light gray; moist; firm; thin bedded; can be trimmed with knife; non

EXPLANATION

CORE LOSS
CORE RECOVERY

Type of hole .... D = Diamond, H = [illegible], S = Shot, C = Churn
Hole sealed .... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Otter Creek Study Site PROJECT STATE Mont. SHEET 4 OF 7 HOLE NO DH74-101

LEGEND

SUITABILITY FOR RECONSTRUCTED PROFILES

▦ SUITABLE

▨ LIMITED SUITABILITY

▥ UNSUITABLE

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

OTTER CREEK STUDY SITE
OTTER CREEK COAL FIELD

GEOLOGIC LOG OF DH 74-101

DRAWN G.T. TAUCHER SUBMITTED
TRACED RECOMMENDED
CHECKED APPROVED

BILLINGS, MONTANA MARCH 1975
SHEETS 1 THROUGH 4 OF 7

1305-600-7

GEOLOGIC LOG OF DRILL HOLE

SHEET 5 OF 7

FEATURE Otter Creek Study Site PROJECT STATE Montana
HOLE NO. DH 74-101 LOCATION * GROUND ELEV. Altimeter 3259 DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 7-10-74 FINISHED 8-9-74 DEPTH OF OVERBURDEN 0.5' TOTAL DEPTH 409.5 BEARING -
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 229.6' 8-6-74 LOGGED BY Taucher LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS:

Hole at 409.5' 8-5-74. 6" CS at 20.0'. NXCS at 227.0'. W.L. at 229.6'. Gravel packed hole to 267.5'. Set 2" plastic pipe to 267.5' (perforated 200.0 to 260.0'). Pulled NXCS from 227.0 to 220.0'

Hole at 409.5' 8-7-74. 6" CS at 20.0', NXCS at 220.0'. Hammered NXCS from 220.0 to 190.0'. Casing very tight.

Hole at 409.5' 8-8-74. 6" CS at 20.0' NXCS at 190.0'. Hammered NXCS from 190.0 to 180.0'. Repaired two tires on 4 x 4.

Hole at 409.5' 8-9-74. 6" CS at 20.0', NXCS at 180.0'. Hammered casing 180.0 to 160.0'. NXCS broke at 60.0'. 100' of NXCS (60.0 to 160.0') left in hole.

8-12-74 moved equipment to DH74-102.

*1850' E. & 1480' N of SW Corner, Sec. 34, T. 3S., R. 45 E.

CORE RECOVERY (%): 100

ELEVATION / DEPTH (FEET):
2857.5 401.5
2851.6 407.4
2851.0 408.0
2849.5 409.5

CLASSIFICATION AND PHYSICAL CONDITION:

fissile; top is silty shale of medium plasticity grading into clayey siltstone with depth; friable; thin bedded, uncemented, fine grain sandstone 260.4 to 260.7 & 262.1 to 262.4'.

265.5-284.5 SANDSTONE: Light gray; moist; fine grain; weakly cemented; friable (can be crushed with difficulty between fingers); broken by drilling on 2 to 6" centers. Soft siltstone 266.4 to 267.0'; 7.9' of uncemented (?) sandstone washed away during drilling between 271.1 to 281.0'.

284.5-286.7 COAL: Broken; hairline vertical fractures; few soft clay streaks.

286.7-298.7 SILTY SHALE: Light gray; moist; moderately hard; thin bedded to massive; difficult cutting with knife; broken by drilling on 6" to 2' core lengths.

298.7-302.0 SILTY LIMESTONE: Light gray; hard; dense; can scrape with knife; massive.

302.0-304.6 SILTY SHALE: Light gray; moderately hard (can be skinned with difficulty by knife); moist; thin bedded to massive; incipient fissility; broken by drilling on 2 to 12" centers; carbonaceous 302.0 to 302.2 & 304.5 to 304.6'.

304.6-305.5 SANDSTONE: Medium gray; moist; compact; fine grain; weakly cemented; friable (can be crushed between fingers); carbonaceous 304.6 to 304.7'.

305.5-312.2 SILTY SHALE: Light gray; moist; moderately hard; thin bedded (incipient fissility) to almost massive; can be trimmed with difficulty by knife; approaching siltstone in places; carbonaceous fragments throughout; carbonaceous 307.8 to 308.0'; moderately plastic.

312.2-313.2 COAL: Broken; horizontal & vertical hairline fractures.

313.2-323.1 SILTSTONE: Light gray; moist; thin bedded or shaley (incipient fissility); sandy; moderately hard; difficult trimming with knife; moderately plastic; few carbonaceous fragments; 2" to 3' core lengths.

323.1-350.3 SANDSTONE: Light gray; moist; fine grain; weakly cemented; moderately hard; friable (can be

EXPLANATION

CORE LOSS
CORE RECOVERY

Type of hole .... D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed .... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X series) Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Otter Creek Study Site PROJECT STATE Mont. SHEET 5 OF 7 HOLE NO. DH74-101

GEOLOGIC LOG OF DRILL HOLE

SHEET 6 OF 7

FEATURE Otter Creek Study Site PROJECT STATE Montana
HOLE NO. DH 74-101 LOCATION * COORDS. N. E. GROUND ELEV. Altimeter 3259 DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 7-10-74 FINISHED 8-9-74 DEPTH OF OVERBURDEN 0.5' TOTAL DEPTH 409.5 BEARING -
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 229.6' 8-6-74 LOGGED BY Taucher LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS | TYPE AND SIZE OF HOLE | CORE RECOVERY (%) | PERCOLATION TESTS: DEPTH (FEET) FROM (P, Cs, or Cm) TO, LOSS (G.P.M.), PRESSURE (P.S.I.), LENGTH OF TEST (MIN.) | ELEVATION (FEET) | DEPTH (FEET) | GRAPHIC LOG | SAMPLES FOR TESTING | CLASSIFICATION AND PHYSICAL CONDITION

*1850' E. & 1480' N. of SW Corner, Sec. 34, T. 3S., R. 45 E.

CLASSIFICATION AND PHYSICAL CONDITION:

crushed between fingers); very fine grain (near siltstone) 323.1 to 333.0'; hard siltstone 328.6 to 329.6'; broken by drilling on 2 to 12" centers.

350.3-351.4 CARBONACEOUS SHALE: Light gray to black; moist; moderately hard; incipient fissility; can be trimmed by knife; near coal 350.3 to 350.6'; carbonaceous fragments 350.6 to 351.4'.

351.4-358.2 SANDSTONE: Light gray; fine grain; moist; weakly cemented; friable (can be crushed between fingers); thin bedded to almost massive; few carbonaceous fragments.

358.2-359.0 SHALE: Medium to dark gray; moist; hard; incipient fissility; can be trimmed by knife; plastic; becoming carbonaceous with depth.

359.0-361.3 COAL: Few horizontal & vertical hairline fractures.

361.3-361.9 SILTY SHALE: Light gray; moist; plastic; moderately hard; can be trimmed by knife; incipient fissility; slightly carbonaceous.

361.9-372.8 SANDSTONE: Light gray; moist; fine grain; thin bedded to massive; friable (crushes between fingers); very weakly cemented; thin bedded (silty & clayey) 363.0 to 365.0'; becoming very silty (approaching siltstone) 371.5 to 372.8'; few thin carbonaceous streaks; broken by drilling on 2 to 6" centers.

372.8-376.9 CLAYEY SILTSTONE & SILTY SHALE: Light to medium gray; clayey siltstone near top grading into silty shale with depth; medium plastic to plastic; moderately hard (can be trimmed by knife); incipient fissility; carbonaceous fragments with highly carbonaceous shale 375.0 to 375.8'; broken by drilling in 1' lengths.

376.9-385.4 COAL: Carbonaceous shale 376.9 to 377.4 & 384.9 to 385.4'; cut by horizontal & vertical hairline fractures; broken by drilling.

385.4-401.5 SANDSTONE: Light gray; moist; fine grain; very weakly cemented (crushes easily between fingers); almost massive with bedding not readily discernible; little or no cement 392.0 to 393.0'; broken by drilling on 1 to 3" centers.

401.5-407.4 SILTY SHALE: Light gray; moist; moderately hard (can be trimmed by knife); almost massive with no bedding

EXPLANATION

CORE LOSS
CORE RECOVERY

Type of hole .... D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed .... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Otter Creek Study Site PROJECT STATE Mont. SHEET 6 OF 7 HOLE NO. DH74-101

GEOLOGIC LOG OF DRILL HOLE

SHEET 7 OF 7

FEATURE Otter Creek Study Site PROJECT STATE Montana
HOLE NO. DH 74-101 LOCATION * COORDS. N E. GROUND ELEV. 3259 DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 7-10-74 FINISHED 8-9-74 DEPTH OF OVERBURDEN 0.5' TOTAL DEPTH 409.5 BEARING -
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 229.6' 8-6-74 LOGGED BY Taucher LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS | TYPE AND SIZE OF HOLE | CORE RECOVERY (%) | PERCOLATION TESTS: DEPTH (FEET) FROM (P, Cs, or Cm) TO, LOSS (G.P.M.), PRESSURE (P.S.I.), LENGTH OF TEST (MIN.) | ELEVATION (FEET) | DEPTH (FEET) | GRAPHIC LOG | SAMPLES FOR TESTING | CLASSIFICATION AND PHYSICAL CONDITION

*1850' E. & 1480' N. of SW Corner, Sec. 34, T. 3S, R. 45 E.

CLASSIFICATION AND PHYSICAL CONDITION:

discernible; plastic when worked; becoming thin bedded siltstone 405.9 to 407.0'.

407.4-408.0 COAL: Broken; few thin shale stringers; horizontal fractures with white colored staining.

408.0-409.5 CARBONACEOUS SHALE: Light to dark gray; moist; moderately hard; incipient fissility; can be trimmed by knife; contains ½" coal filled vertical fracture (?).

EXPLANATION

CORE LOSS
CORE RECOVERY

Type of hole .... D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed .... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Otter Creek Study Site PROJECT STATE Mont. SHEET 7 OF 7 HOLE NO. DH-74-101

Legend on Plate 9

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

OTTER CREEK STUOY SITE
OTTER CREEK COAL FIELO

GEOLOGIC LOG OF DH74-101

DRAWN G.J. TAUCHER SUBMITTED
TRACED RECOMMENDED
CHECKED APPROVED
BILLINGS, MONTANA MARCH 1975
SHEETS 5 THROUGH 7 OF 7
1305-600-8

PLATE 11

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 4

FEATURE Otter Creek Study Site PROJECT Altimeter STATE Montana
HOLE NO DH 74-102 LOCATION * GROUND ELEV. 3191 DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 8/13/74 FINISHED 9/6/74 DEPTH OF OVERBURDEN - TOTAL DEPTH 334.2 BEARING -
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 120.0' 9/4/74 LOGGED BY Taucher LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

Hole started 8/13/74. Rockbit 0 to 3.5'. 2-3/4" core 3.5 to 17.7'. Set 5" CS to 8.6'.

8/14/74. Heavy rain. Did not go to drill rig.

Hole at 17.7' 8/15/74. 5" CS at 8.6'. 2-3/4" core 17.7 to 45.1'. Losing some water last run.

Hole at 45.1' 8/16/74. 5" CS at 8.6'. W.L. at 43.0'. 2-3/4" core 45.1 to 72.7'. Losing small amount of water.

Hole at 72.7' 8/19/74. 5" CS at 8.6'. Hole dry. 2-3/4" core 72.7 to 112.7'.

*2420' W. & 1700' N. of SE Corner Sec. 26, T. 3 S., R. 45 E.

CORE RECOVERY (%): Rock bit, 100, 100, 100, 100, 100, 100, 74, 98, 100, 100, 90, 40, 78, 100, 100, 100, 100, 100, 100, 100, 100, 100

SAMPLES
- Lab Sample G-11 3.5 to 7.6'
- Lab Sample G-12 9.6 to 16.0'
- Lab Sample G-13 18.0 to 26.5'
- Lab Sample G-14 28.0 to 43.5'
- Lab Sample G-15 50.4 to 67.5'
- Lab Sample G-16 67.5 to 84.5'
- Lab Sample G-17 91.0 to 100.0'

ELEVATION (FEET)	DEPTH (FEET)
187.5	3.5
187.3	3.7
183.4	7.6
182.0	9.0
175.0	16.0
173.8	17.2
171.5	19.5
167.3	23.7
166.6	24.4
163.3	27.7
102.3	88.7
101.4	89.6

CLASSIFICATION AND PHYSICAL CONDITION

FT. UNION FORMATION - TERTIARY

0-3.5 SANDSTONE: Ridge former; only silt & hard sandstone chips recovered.

3.5-3.7 SANDSTONE: Light gray; dry; fine grain; weakly cemented; friable: can be trimmed by knife.

3.7-7.6 SILTSTONE: Tan; oxidized; damp; sandy; thin-bedded to almost massive; some clay (low plasticity); friable; can be trimmed by knife; becoming more sandy with depth.

7.6-9.0 SILTY SHALE: Tan; damp; oxidized; soft (indented by thumb); silty; moderately plastic.

9.0-16.0 SILTY SHALE: Tan & oxidized 9.0 to 11.0'; light gray 11.0 to 16.0'; incipient fissility; moderately hard (can be trimmed by knife); silty; moderately plastic.

16.0-17.2 SILTSTONE: Tan & oxidized; moist; firm 16.0 to 16.8'; soft 16.8 to 17.2'; can be trimmed by knife.

17.2-19.5 SILTY SHALE: Tan & oxidized 17.2 to 18.0' & 19.0 to 19.5'; light gray 18.0 to 19.0'; moist; almost massive with few thin-bedded zones; very silty; incipient fissility; can be trimmed by knife.

19.5-23.7 SHALE: Medium gray with dark gray carbonaceous zones 23.5 to 23.7'; moist; firm; incipient fissility; plastic: thin-bedded; can be trimmed by knife.

23.7-24.4 COAL: Broken; hairline vertical & horizontal fractures.

24.4-27.7 SHALE: Light to medium gray with tan, oxidized zone 27.0 to 27.7'; thin-bedded; incipient fissility; slightly carbonaceous. Can be trimmed by knife. Broken in 6 to 18" lengths.

27.7-88.7 SANDSTONE: Light gray to tan; slightly oxidized; moist; weakly to noncemented; friable (can be crushed between fingers); silty; thin-bedded; fine grain, very weakly cemented, friable sandstone 27.7 to 33.0'; massive, very fine grain, weakly cemented, friable sandstone (broken on 3 to 12" centers) 33.0 to 43.1'; fine grain, uncemented (pulverized by drilling), friable sandstone 43.1 to 50.1'; massive, very fine grain, weakly cemented, friable sandstone (core lengths 2 to 12") 50.1 to 70.7'; tan, oxidized, very silty, uncemented, fine grain sandstone (pulverized by drilling)

EXPLANATION

CORE LOSS
CORE RECOVERY

Type of hole . . . O = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed . . . P = Packer, Cm = Cemented, Cb = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Otter Creek Study Site PROJECT STATE Montana SHEET 1 OF 4 HOLE NO DH74-102

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 4

FEATURE Otter Creek Study Site PROJECT Altimeter STATE Montana
HOLE NO DH 74-102 LOCATION * GROUND ELEV 3191 DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 8/13/74 FINISHED 9/6/74 DEPTH OF OVERBURDEN - TOTAL DEPTH 334.2 BEARING -
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 120.0' 9/4/74 LOGGED BY Taucher LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

Hole at 112.7' 8/20/74. 5" CS at 8.6'. Hole dry. Washed through 32' of cave & cuttings. 2-3/4" core 112.7 to 136.4'. Quit drilling at 2 p.m. because of rain.

Hole at 136.4' 8/21/74. 5" CS at 8.6'. W.L. at 105.0'. Washed through 30' of cave & cuttings. 2-3/4" core 136.4 to 163.9'.

Hole at 163.9' 8/22/74. 5" CS at 8.6'. W.L. at 116.4'. 2-3/4" core 163.9 to 190.2'.

Hole at 190.2' 8/23/74. 5" CS at 8.6'. W.L. at 120.0'. 2-3/4" core 190.2 to 205.2'. Repaired equipment.

*2420' W. & 1700' N. of SE Corner Sec. 26, T. 3 S., R. 45 E.

CORE RECOVERY (%): 100, 100, 100, 84, 100, 86, 100, 96, 100, 100, 90, 100, 100, 100, 100, 100, 100, 100, 100, 91, 100, 100, 100

SAMPLES
- Lab Sample G-18 102.0 to 110.0'
- Lab Sample G-19 110.0 to 124.5'
- Lab Sample G-20 188.3 to 200.0'

ELEVATION (FEET)	DEPTH (FEET)
3090.7	100.3
3080.3	110.7
3066.5	124.5
3064.9	126.1
3005.8	185.2
3002.7	188.3
2998.6	192.4
2992.3	198.7

CLASSIFICATION AND PHYSICAL CONDITION

70.7 to 72.7'; Tan, oxidized, very silty (near siltstone), friable, fine grain, thin-bedded sandstone (broken on 1" to 2" centers) 72.7 to 73.9'; tan, fine grain, massive, weakly cemented, friable sandstone (6" to 3' core lengths) 73.9 to 84.7'; tan, oxidized, broken, moderately hard (can be trimmed by knife), moderately plastic, silty shale 84.7 to 85.2'; silty (very silty 87.0 to 87.4'), tan, oxidized, friable, uncemented, thin-bedded sandstone (broken to pulverized) 85.2 to 88.7'; several 1" oxidized zones 54.1 to 55.7'; oxidized 63.8 to 64.0 & 68.2 to 68.4'; 80° joint 63.5 to 64.5'.

88.7-89.6 SILTY SHALE & CLAYEY SILTSTONE: Tan & oxidized 88.7 to 89.1'; light gray 89.1 to 89.6'; moist; firm; clayey siltstone 88.7 to 89.1'; near fissile silty shale 89.1 to 89.6'; can be trimmed by knife.

89.6-100.3 SANDY SILTSTONE: Light gray with medium gray bands; moist; thin-bedded; friable (near silty sandstone); sand is very fine grain; can be trimmed by knife; soft & badly broken 89.6 to 91.5'; broken in 1" to 1' pieces by drilling 91.5 to 100.3'; 80° fracture 95.0 to 95.6' and 96.5 to 97.0'; very soft (easily crumbled) 96.7 to 98.7'.

100.3-110.7 SILTY SHALE: Light gray; moist; firm; incipient fissility; very silty (approaching clayey siltstone); thin-bedded to almost massive in places; moderately plastic; can be trimmed easily with knife; broken by drilling in 3 to 12" pieces.

110.7-124.5 CLAYEY TO SANDY SILTSTONE: Light gray; moist to wet with depth; thin-bedded ; crumbles easily; can be trimmed by knife.; contains sandy & clayey zones; low plasticity when reworked; plastic, medium gray shale 121.7 to 122.7'.

124.5-126.1 SHALE: Medium to dark gray; wet; incipient fissility; plastic; carbonaceous; becoming more carbonaceous with depth; can be trimmed by knife.

126.1-185.2 COAL: Wet; mostly chips with few 1 to 3" fragments 126.1 to 167.6'; 1" to 1' core lengths 167.6 to 185.2'; contains vertical & horizontal hairline fractures with some fracture faces exhibiting minor staining.

185.2-188.3 CARBONACEOUS SHALE: Medium to dark gray; wet; carbonaceous with thin coal streaks; plastic; incipient fissility; can be cut by knife; lower 1' contains ½" mud filled (dike-like) fracture and several 60 to 70° poorly developed slickensides (small fault zone).

EXPLANATION

CORE LOSS
CORE RECOVERY

Type of hole . . . O = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed . . . P = Packer, Cm = Cemented, Cb = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Otter Creek Study Site PROJECT STATE Montana SHEET 2 OF 4 HOLE NO DH74-102

GEOLOGIC LOG OF DRILL HOLE

SHEET 3 OF 4

FEATURE Otter Creek Study Site PROJECT Altimeter STATE Montana
HOLE NO DH 74-102 LOCATION * GROUND ELEV 3191 DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 8/13/74 FINISHED 9/6/74 DEPTH OF OVERBURDEN - TOTAL DEPTH 334.2 BEARING -
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 120.0' 9/4/74 LOGGED BY Taucher LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

Hole at 205.2' 8/26/74. 5" CS at 8.6'. W.L. at 119.2'. Washed through 30' of cave & cuttings. NX core 205.2 to 252.0'.

Hole at 252.0' 8/27/74. 5" CS at 8.6'. W.L. at 120.0'. NX core 252.0 to 278.4'. Stuck drill rods at 278.4'.

Hole at 278.4' 8/28/74. - 5" CS at 8.6'. Reamed NXCS to 221.0'.

Hole at 278.4' 8/29/74. 5" CS at 8.6'. Reamed hole 221.0 to 278.4'. Pulled rods & NXCS. NX core 278.4 to 280.0'.

Hole at 278.4' 8/30/74. 5" CS at 8.6'. W.L. at 120.0'. Heavy rain stopped work.

Hole at 280.0' 9/3/74. 5" CS at 8.6'. W.L. at 120.0'. NX core 280.0 to 309.2'

*2420' W. & 1700' N. of SE Corner Sec. 26, T. 3 S., R. 45 E.

CORE RECOVERY (%): 100, 93, 76, 100, 95, 96, 66, 94, 100, 31, 100, 100, 100, 100

SAMPLES
- Lab Sample G-21 203.0 to 212.0'

ELEVATION (FEET)	DEPTH (FEET)
2990.4	200.6
2989.9	201.1
2988.6	202.4
2986.8	204.2
2978.1	212.9
2956.3	234.7
2952.6	238.4
2913.5	277.5
2909.0	282.0
2907.7	283.3
2905.0	286.0
2901.8	289.2
2891.3	299.7

CLASSIFICATION AND PHYSICAL CONDITION

188.3-192.4 SANDY SILTSTONE GRADING TO CLAYEY SILTSTONE: Light to medium gray; wet; slightly carbonaceous in upper 2'; moderately hard but can be trimmed by knife; cracks with difficulty between fingers; almost massive; grades to clayey siltstone with depth; few small (-1"), nodular concretions in lower 2'.

192.4-198.7' SILTY SANDSTONE: Light gray; wet; friable; cross-bedded; very silty (near siltstone); fine grain; can be trimmed by knife; becoming more silty with few thin clay streaks below 195.0'.

198.7-200.6 SILTY SHALE: Light gray; wet; firm; almost massive; can be trimmed by knife; incipient fissility; moderately hard; becoming carbonaceous with depth.

200.6-201.1 COAL: Wet; broken; vertical & horizontal hairline fractures.

201.1-202.4 SHALE: Medium to dark gray; wet; fissile; air slacks; plastic; carbonaceous; core lengths 1 to 8".

202.4-204.2 SANDY SILTSTONE: Light gray with dark gray carbonaceous beds; thin-bedded; friable; approaching fine grain sandstone; 1 to 3" core lengths.

204.2-212.9 SANDSTONE: Light gray; wet; fine grain; thin-bedded with some carbonaceous material 204.2 to 206.2'; almost massive 206.2 to 212.9'; weakly cemented & friable 204.2 to 209.2'; uncemented 209.2 to 212.9'.

212.9-234.7 SILTY SHALE: Light to medium gray; wet; moderately hard (can be trimmed with difficulty by knife); bedding not readily discernible; plastic when reworked; silty shale 212.9 to 218.0'; tan, thin-bedded to massive, hard, calcareous shale or marl 218.0 to 219.0'; shale 219.0 to 228.0' with carbonaceous zones 226.5 to 228.0' and sandstone 227.7 to 227.8'; medium to dark gray, thin-bedded, carbonaceous sandstone 228.0 to 228.6'; coal & carbonaceous shale 228.6 to 228.7'; silty shale 228.7 to 234.7' with dark gray carbonaceous zones 228.7 to 228.9' & scattered thin sandy zones.

234.7-238.4 SILTY SANDSTONE: Light gray; wet; very fine grain; silty; friable; begins to wash away during drilling; mica flakes; core lengths 1 to 3".

238.4-277.5 SANDY SILTSTONE: Light gray; wet; very fine grain sand (approaching silty sandstone); can be trimmed with knife & crushed between fingers; thin-

EXPLANATION

CORE LOSS
CORE RECOVERY

Type of hole . . . O = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed . . . P = Packer, Cm = Cemented, Cb = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Otter Creek Study Site PROJECT STATE Montana SHEET 3 OF 4 HOLE NO DH74-102

GEOLOGIC LOG OF DRILL HOLE

SHEET 4 OF 4

FEATURE Otter Creek Study Site PROJECT Altimeter STATE Montana
HOLE NO DH 74-102 LOCATION * GROUND ELEV 3191 DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 8/13/74 FINISHED 9/6/74 DEPTH OF OVERBURDEN - TOTAL DEPTH 334.2 BEARING -
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 120.0' 9/4/74 LOGGED BY Taucher LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

Hole at 309.2' 9/4/74. 5" CS at 8.6'. W.L. at 120.0'. NX core 309.2 to 334.2'. Drill mud used in hole from 280.0 to 334.2'. Losing some water.

Hole at 334.2' 9/5/74. 5" CS at 8.6'. W.L. at 120.0'. Gravel packed hole 201 to 334.2'. Installed 196' of 2" plastic pipe (perforated 120 to 180'). Pulled 5" CS.

9/6/74 Moved equipment to DH74-103.

*2420' W. & 1700' N. of SE Corner Sec. 26, T. 3 S., R. 45 E.

CORE RECOVERY (%): 100, 100, 100, 100, 100, 98, 100

ELEVATION (FEET)	DEPTH (FEET)
2886.8	304.2
2878.7	312.3
2871.0	320
2861.7	329.3
2856.8	334.2

CLASSIFICATION AND PHYSICAL CONDITION

bedded, micaceous shale 243.0 to 244.0', 245.7 to 246.0' & 247.0 to 247.2'; few clay, silt & sand stringers throughout three 1/8" to 1/4" coal stringers 274.4' to 274.6'; 3 to 12" core lengths.

277.5-282.0' SILTY SANDSTONE: Light gray; wet; fine grain; silty; weakly cemented; massive with few thin-bedded zones; friable; can be trimmed with knife; 90° joint 280.0 to 281.0'; 2 to 12" core lengths.

282.0-283.3 SILTY SHALE: Medium gray; wet; moderately plastic; massive with thin-bedded carbonaceous zone 282.3 to 282.6'; can be trimmed by knife.

283.3-286.0 SILTY SANDSTONE: Light gray; wet; weakly cemented; friable; very silty (approaching sandy siltstone); fine grain; micaceous; 90° joint 285.0 to 286.0'.

286.0-289.2 SILTY SHALE: Medium gray; wet; moderately plastic; almost massive; can be trimmed by knife; incipient fissility; several hard, 2", tan, calcareous concretions.

289.2-299.7 COAL: Broken along 90° near fresh fractures 294.2 to 299.7'; shale 289.4 to 289.5'; plastic; carbonaceous shale 290.0 to 290.5'.

299.7-304.2 SILTY SANDSTONE & SANDY SILTSTONE: Light gray with dark gray carbonaceous zone 299.7 to 300.3'; wet; grades from silty sandstone to sandy siltstone; micaceous; friable; can be trimmed by knife; 90° fracture 302.0 to 303.0'; 2 to 12" core lengths.

304.2-312.3 SILTY SHALE & CLAYEY SILTSTONE: Light gray; wet; firm; can be crushed between fingers with difficulty; large amounts of very fine sand; micaceous; grades from silty shale to clayey siltstone; moderately plastic when reworked; 90° fracture 310.0 to 310.6' & 311.0 to 312.0'.

312.3-320.0 SANDSTONE: Light gray; wet: fine grain; massive; can be crushed between fingers with difficulty; weakly cemented with hard, moderately cemented zone 319.2 to 320.0'.

320.0-329.3 SANDY SILTSTONE: Light gray; wet; thin-bedded to laminated; numerous dark gray, carbonaceous streaks; moderately hard (can be crushed between fingers with difficulty); very sandy (approaching silty sandstone); can be trimmed by knife; micaceous; broken along 70 to 90° fractures 326.0 to 327.5'.

329.3-334.2 SILTY SHALE: Light to medium gray; wet; moderately hard; can be trimmed by knife with difficulty; thin-bedded to almost massive; incipient fissility; carbonaceous streaks 329.4 to 329.5; hard, calcareous cemented concretions 332.2 to 332.6 & 333.6 to 333.9'.

EXPLANATION

CORE LOSS
CORE RECOVERY

Type of hole . . . O = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed . . . P = Packer, Cm = Cemented, Cb = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Otter Creek Study Site PROJECT STATE Montana SHEET 4 OF 4 HOLE NO DH74-102

Legend on Plate 9

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

OTTER CREEK STUDY SITE
OTTER CREEK COAL FIELD

GEOLOGIC LOG OF DH 74-102

DRAWN O.J. TAUCHER SUBMITTED
TRACED RECOMMENDED
CHECKED APPROVED

BILLINGS, MONTANA MARCH 1975
SHEETS 1 THROUGH 4 OF 4
1305-600-9

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 3

FEATURE Otter Creek Study Site PROJECT STATE Montana
HOLE NO DH 74-103 LOCATION * Altimeter GROUND ELEV. 3194 DIP (ANGLE FROM HORIZ.) Vertical
COORDS. N. E.
BEGUN 9/9/74 FINISHED 9/20/74 DEPTH OF OVERBURDEN 1.0 TOTAL DEPTH 220.1 BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 141.2' 1/22/75 LOGGED BY Taucher LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

Hole started 9/9/74, Drive samples 0 to 8.5'.

Hole at 8.5' 9/10/74. 2-3/4" core 8.5 to 28.1' Losing water. Reamed hole & set 6" CS to 18.6.' Losing some water after casing set.

Hole at 28.1' 9/11/74. 6" CS at 18.6'. Hole dry. 2-3/4" core 28.1 to 69.8'.

Hole at 69.8' 9/12/74. 6" CS at 18.6'. W.L. at 47.5'. 15' of cave & cuttings in hole. 2-3/4" core 69.8 to 105.8'.

*960' W. & 1060' S. of NE Corner Sec. 34, T. 3 S., R. 45 E.

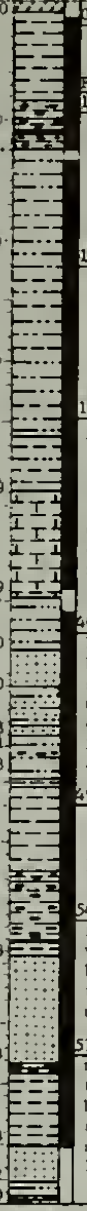
CORE RECOVERY (%): 100, 100, 98, 100, 100, 92, 100, 100, 100, 100, 100, 100, 80, 100, 88, 100, 100, 100, 100, 100, 100, 96

PERCOLATION TESTS

Lab Sample	From	To
G-22	1.5	8.5'
G-23	8.5	12.5'
G-24	13.5	22.0'
G-25	22.0	35.0'
G-26	35.0	40.9'
G-27	40.9	49.0'
G-28	50.1	58.3'
G-29	58.3	64.8'
G-30	64.8	79.3'
G-31	79.3	88.3'
G-32	88.3	95.3'

ELEVATION (FEET)	DEPTH (FEET)
3193.0	1.0
3184.0	
3181.5	12.5
3153.1	40.9
3144.1	49.9
3140.0	54.0
3137.0	57.0
3133.7	60.3
3132.9	61.1
3129.2	64.8
3114.7	79.3
3105.7	88.3
3098.7	95.3
3095.8	98.2
3094.0	100.0

GRAPHIC LOG



CLASSIFICATION AND PHYSICAL CONDITION

0-1.0 SANDY CLAY: Tan; soft; dry; approx. 40% fine, uniform sand; approx. 60% low plasticity fines (CL).

FT. UNION FORMATION - TERTIARY

1.0-10.0 SHALE: Gray - brown; oxidized with oxidation decreasing with depth; moist; cuts easily with knife; plastic; incipient fissility; gypsum crystals & inclusions throughout; laminated; becoming dark gray & slightly carbonaceous 8.5 to 10.0'; broken in 1 to 3" pieces.

10.0-12.5 CARBONACEOUS SHALE & COAL: Dark gray to black; moist; plastic; thin (-½") coal stringers throughout; coal 10.8 to 11.2'; fossiliferous. Trims easily with knife. Incipient fissility. Some gypsum along bedding planes; core lengths 2 to 3".

12.5-40.9 CLAYEY SILTSTONE WITH SILTY CLAY: Brown & oxidized 12.5 to 36.3'; light gray 36.3 to 40.9'; mostly clayey siltstone with zones of low plasticity. silty shale 12.5 to 36.3'; silty shale 36.3 to 40.9'; moist; laminated to almost massive; can be trimmed by knife & crushes moderately easy between fingers. Several, fresh, 90° fractures 39.5 to 40.5'; -½" to 1' core lengths.

40.9-49.9 MARL OR CALCAREOUS SHALE: Light gray; moist; hard; can be scratched by knife; cemented; less cement & slightly softer below 45.1'; mostly massive with few thin-bedded zones below 45.1'; plastic when crushed & reworked; 2 - irregular 70 to 90° oxidized joints 43.6 to 45.1'; 6" to 1½' core lengths.

49.9-54.0 CLAYEY SILTSTONE: Light gray to tan; slightly oxidized; moist; can be trimmed by knife & crushed between fingers; low plasticity; thin-bedded to laminated; 2 to 6" core lengths.

54.0-57.0 SILTY SANDSTONE: Tan; moist; friable (crushes easily between fingers); very fine grain; thin-bedded; silty; begins to wash away during drilling; few thin, carbonaceous streaks; micaceous; maximum 2" core length.

57.0-60.3 SANDY SILTSTONE: Tan; moist; micaceous; laminated to almost massive; trims easily with knife; crushes easily between fingers; very fine sand; clayey siltstone 58.5 to 58.9'; few carbonaceous streaks 60.1 to 60.3'; -½ to 3" core lengths.

EXPLANATION

☐ CORE LOSS
■ CORE RECOVERY

Type of hole .... D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed .... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) .. Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Otter Creek Study Site PROJECT STATE Mont. SHEET 1 OF 3 HOLE NO DH74-103

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 3

FEATURE Otter Creek Study Site PROJECT STATE Montana
HOLE NO DH 74-103 LOCATION * Altimeter GROUND ELEV. 3194 DIP (ANGLE FROM HORIZ.) Vertical
COORDS. N. E.
BEGUN 9/9/74 FINISHED 9/20/74 DEPTH OF OVERBURDEN 1.0 TOTAL DEPTH 220.1 BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 141.2' 1/22/75 LOGGED BY Taucher LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

Hole at 105.8' 9/13/74. 6" CS at 18.6'. W.L. at 60.0'. Washed through 60' of cave & cuttings. 2-3/4" core 105.8 to 132.5'.

Hole at 132.5' 9/16/74. 6" CS at 18.6'. W.L. at 97.0'. Washed through 30' of cave & cuttings. 2-3/4" core 132.5 to 164.0'.

Hole at 164.0' 9/17/74. 6" CS at 18.6'. W.L. at 98.2'. Washed through 60' of cave & cuttings. 2-3/4" core 164.0 to 195.1'.

*960' W. & 1060' S. of NE Corner Sec. 34, T. 3 S., R. 45 E.

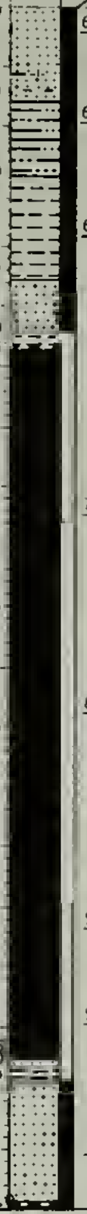
CORE RECOVERY (%): 100, 100, 100, 93, 100, 100, 100, 100, 100, 100, 100, 100, 100, 100, 100, 100, 100, 100, 100, 90, 100, 100

PERCOLATION TESTS

Lab Sample	From	To
G-33	100.0	107.9'
G-34	107.9	114.0'
G-35	114.0	122.0'
G-36	122.0	127.0'
G-37	189.4	200.0

ELEVATION (FEET)	DEPTH (FEET)
3094.0	100.0
3086.1	107.9
3080.0	114.0
3071.3	122.7
3067.0	127.0
3065.5	128.5
3006.5	187.5
3006.0	188.0
3004.6	189.4
2994.0	200.0

GRAPHIC LOG



CLASSIFICATION AND PHYSICAL CONDITION

60.3-61.1 SILTY SANDSTONE: Light gray; moist; thin-bedded; very fine grain; friable (pulverizes easily between fingers).

61.1-64.8 SANDY SILTSTONE: Tan; oxidized; moist; soft; thin-bedded; friable; contains zones of silty sandstone; carbonaceous 62.4 to 62.9'; ½ to 3" core lengths.

64.8-79.3 SILTY SHALE: Tan & oxidized 64.8 to 65.4'; light gray & calcareous 65.4 to 72.4'. Medium gray & slightly carbonaceous 72.4 to 73.2'; dark gray & carbonaceous 73.2 to 78.3' with -1" coal seam 78.2 to 78.3'; light gray 78.3 to 78.8'; tan & oxidized 78.8 to 79.3'; moist; thin-bedded to almost massive in places. Very firm (difficult cutting with knife) 64.8 to 71.2'; firm (can be trimmed by knife) 71.2 to 79.3'; incipient fissility; 90° joint 70.3 to 71.2' & 75.8 to 76.2'; 1" to 1' core lengths.

79.3-88.3 SANDSTONE: Tan; moist; oxidized; friable (crushes easily between fingers); little, if any cement; pulverized 79.3 to 83.6'; moderately firm 83.6 to 88.3'; very fine grain; several, oxidized, 70 to 90° irregular fractures 83.6 to 84.6'; oxidized with horizontal & vertical fractures 85.0 to 85.5'; 2 - 90° fractures 87.0 to 88.3'.

88.3-95.3 SILTY SHALE: Medium gray & slightly carbonaceous 88.3 to 88.8'; tan & oxidized with ½" coal seam 88.8 to 89.6'; light gray 89.6 to 95.3' with thin slightly carbonaceous zone 95.1 to 95.3'; moist; thin-bedded to laminated; firm; can be trimmed by knife; probably calcareous; approaches clayey siltstone in places; low to medium plasticity; incipient fissility.

95.3-98.2 SANDSTONE: Medium gray; moist; hard; moderately cemented; can be scratched by knife; fine grain; massive; 2 to 18" core lengths.

98.2-100.0 CLAYEY SILTSTONE: Light gray 98.2 to 99.3'; tan & oxidized 99.3 to 100.0'; moist; firm; can be trimmed by knife; thin-bedded to massive; laminated, silty sandstone 99.5 to 99.8'; 1 to 8" core lengths.

100.0-107.9 SILTY SANDSTONE: Tan; moderately oxidized; moist; very fine grain; silty; friable (pulverized easily between fingers); 90° fracture

EXPLANATION

☐ CORE LOSS
■ CORE RECOVERY

Type of hole .... D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed .... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) .. Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Otter Creek Study Site PROJECT STATE Mont. SHEET 2 OF 3 HOLE NO DH74-103

GEOLOGIC LOG OF DRILL HOLE

SHEET 3 OF 3

FEATURE Otter Creek Study Site PROJECT STATE Montana
HOLE NO DH 74-103 LOCATION * Altimeter GROUND ELEV. 3194 DIP (ANGLE FROM HORIZ.) Vertical
COORDS. N. E.
BEGUN 9/9/74 FINISHED 9/20/74 DEPTH OF OVERBURDEN 1.0 TOTAL DEPTH 220.1 BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 141.2' 1/22/75 LOGGED BY Taucher LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

Hole at 195.1' 9/18/74. 6" CS at 18.6'. W.L. at 98.2'. Washed through 80.0' of cave & cuttings. 2-3/4" core 195.1 to 220.1'. Reamed hole (6") to 52.0'.

Hole at 220.1' 9/19/74. 6" CS at 18.6'. Reamed hole (6") 52.0 to 220.0'.

Hole at 220.1' 9/20/74. 6" CS at 18.6'. W.L. at 100.0'. Set 4" plastic pipe to 189.0'. Perforated 109 to 169'. Pulled casing & moved equipment.

*960' W. & 1060' S. of NE Corner Sec. 34, T. 3 S., R. 45 E.

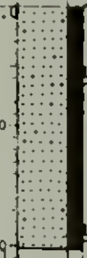
CORE RECOVERY (%): 96, 98, 100, 100

PERCULATION TESTS

Lab Sample	From	To
G-38	200.0	221.0

ELEVATION (FEET)	DEPTH (FEET)
2994.0	200.0
2973.9	220.1

GRAPHIC LOG



CLASSIFICATION AND PHYSICAL CONDITION

104.4 to 105.4'; several, thin (2 to 3"), hard, silty concretions (?) 105 to 107.9'.

107.9-114.0 SANDY TO CLAYEY SILTSTONE: Tan, oxidized & sandy 107.9 to 111.0'; light gray & clayey 111.0 to 114.0'; moderately firm 107.9 to 111.0'; firm 111.0 to 114.0'; can be trimmed by knife; 90° fracture 112.3 to 113.3'; 2 to 12" core lengths.

114.0-122.7 SILTY SHALE: Light gray; moist; moderately firm; can be trimmed by knife; silty; moderately plastic; incipient fissility; thin-bedded to almost massive; several, irregular, 90° fractures 119.0 to 120.0' & 121.0 to 122.0'; core lengths 3 to 12".

122.7-127.0 SANDSTONE: Light gray; moist; uncemented; fine grain; thin-bedded to laminated with few laminations being slightly carbonaceous; friable (crushes easily between fingers).

127.0-128.5 SHALE: Light gray; moist; firm; can be trimmed by knife; incipient fissility; slightly carbonaceous in lower part; 6" core lengths.

128.5-187.5 COAL: Moist to wet; chips 128.5 to 132.5'; chips to 3" fragments 132.5 to 154.7'; chips 154.7 to 159.2'; excellent core with pieces 1 to 12" in length 159.2 to 187.5'; contains few horizontal & vertical fractures (some with white (?) coating).

187.5-188.0 SANDSTONE: Medium to dark gray; moist; fine grain; friable; uncemented; few carbonaceous streaks.

188.0-189.4 SHALE: Light gray; moist; silty; incipient fissility; can be trimmed by knife.

189.4-200.0 SILTY SANDSTONE: Light gray; moist; silty; very fine grain; thin-bedded in places; friable (can be crushed between fingers). Weakly cemented; 90° fracture 193.5 to 195.0'; clayey zone 199.5 to 199.8'; few carbonaceous streaks; 1 to 12" core lengths.

200.0-220.1 SANDSTONE: Light gray; moist; fine grain; compact; friable (can be crushed between fingers); weakly cemented; cross-bedded; several, parallel, 80° fractures 208.0 to 208.5'; core lengths 2 to 18".

EXPLANATION

☐ CORE LOSS
■ CORE RECOVERY

Type of hole .... D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed .... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) .. Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Otter Creek Study Site PROJECT STATE Mont. SHEET 3 OF 3 HOLE NO DH74-103

Legend on Plate 9

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

OTTER CREEK STUDY SITE
OTTER CREEK COAL FIELD

GEOLOGIC LOG OF DH 74-103

DRAWN G. J. TAUCHER SUBMITTED
TRACED RECOMMENDED
CHECKED APPROVED

BILLINGS, MONTANA MARCH 1974
SHEETS 1 THROUGH 3 OF 3
1305-600-10

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 3

FEATURE Otter Creek Study Site PROJECT . . . STATE Montana
DH HOLE NO 74-104 LOCATION * ALTIMETER GROUND ELEV 3204 DIP (ANGLE FROM HORIZ.) Vertical
COORDS. N. . . E. . .
BEGUN 9/23/74 FINISHED 10/2/74 DEPTH OF OVERBURDEN . TOTAL DEPTH 222.5 BEARING . .
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 134.5' 10/2/74 LOGGED BY Tauchet LOG REVIEWED BY . .

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

9/23/74. Moved rig & set up equipment. Rockbit 0 to 4.6'. 2-3/4" core 4.6 to 27.0'. 6" CS set to 9.0'.

Hole at 27.0' 9/24/74. 6" CS at 9.0'. W.L. at 9.0'. 2-3/4" Core 27.0 to 79.2'.

Hole at 79.2' 9/25/74. 6" CS at 9.0'. Hole dry. Washed through 10' of cave & cuttings. 2-3/4" core 79.2 to 121.7'.

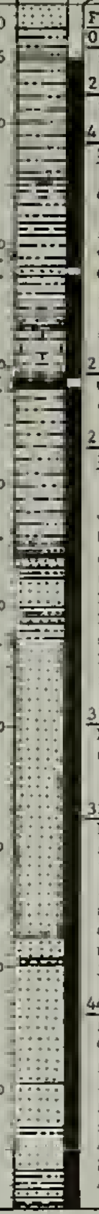
*490' W. & 1710' S of NE Corner Sec. 26, T. 3 S., R. 45 E.

CORE RECOVERY (%): Rock bit, 86, 100, 100, 70, 82, 90, 100, 100, 100, 100, 100, 100, 100, 100, 100, 100, 100, 100, 75, 76, 80, 80

PERCOLATION TESTS

Lab Sample G-39 4.6 to 9.6'
Lab Sample G-40 9.6 to 21.9'
Lab Sample G-41 22.6 to 31.1'
Lab Sample G-42 32.0 to 44.8'
Lab Sample G-43 44.8 to 53.1'
Lab Sample G-44 53.1 to 62.8'
Lab Sample G-45 62.8 to 72.8'
Lab Sample G-46 72.8 to 83.8'
Lab Sample G-47 83.8 to 93.2'
Lab Sample G-48 93.2 to 105.5'

ELEVATION (FEET)	DEPTH (FEET)
3202.0	2.0
3199.4	4.6
3182.1	21.
3181.4	22.
3172.9	31.
3172.0	32.
3159.2	44.
3150.9	53.



CLASSIFICATION AND PHYSICAL CONDITION

FT. UNION FORMATION - TERTIARY

0-2 SANDSTONE: Rockbit - only chips recovered.

2-4.6 SILTSTONE: Rockbit - only chips recovered.

4.6-21.9 CLAYEY SILTSTONE WITH SILTY SHALE: Tan & oxidized 4.6 to 10.0' & 17.0 to 18.2'; light gray 10.0 to 17.0' & 18.2 to 21.9'; dry to moist; laminated to thin-bedded; mostly silt with fine sand & clay; low to moderate plasticity when reworked; incipient fissility. Can be crushed with difficulty between fingers. 1 to 2" core lengths 4.6 to 15.0' & 8 to 8" 15.0 to 21.9'; silty shale 14.6 to 16.0' & 18.2 to 19.2'.

21.9-22.6 SILTY SANDSTONE: Light gray; moist; uncemented; friable (crushes easily between fingers); fine grain.

22.6-31.1 SILTY SHALE WITH CLAYEY SILTSTONE: Tan & oxidized 22.6 to 23.0'; light gray 23.0 to 31.1'; moist; firm (can be trimmed by knife) 22.6 to 26.0'; very firm to almost hard (can be scrape by knife) 26.0 to 26.7'; soft (cuts easily with knife) 26.7 to 27.0'; firm to very firm (can be trimmed by knife) 27.0 to 31.1'; zones 26.0 to 26.7' & 27.0 to 31.1' are calcareous; clayey siltstone 22.6 to 24.6'; plastic shale 26.7 to 27.0'; laminated to thin-bedded; incipient fissility.

31.1-32.0 COAL & CARBONACEOUS SHALE: Firm, dark gray, fossiliferous & carbonaceous shale 31.1 to 31.6'; coal 31.6 to 32.0'.

32.0-44.8 CLAYEY SILTSTONE & SILTY SHALE: Light gray; moist; predominantly clayey siltstone but varies to silty shale; low to moderate plasticity when reworked; firm to very firm (can be trimmed or scraped with knife); thin-bedded to almost massive; incipient fissility; near vertical fractures 32.0 to 34.0' & 35.0 to 36.0'; core lengths 1 to 12".

44.8-53.1 SILTSTONE WITH SANDSTONE: Light gray to tan & slightly oxidized 44.8 to 47.4'; light gray 47.4 to 50.4'; light gray to tan & slightly oxidized 50.4 to 53.1'; soft, pulverized, silty, fine grain sandstone 44.8 to 45.0'; clayey siltstone 45.0 to 45.6'; silty shale 45.6 to 45.8'; siltstone 45.8 to 46.0'; hard, cemented, fine grain sandstone 46.0 to 46.9'; clayey siltstone 46.9 to

EXPLANATION

CORE LOSS
CORE RECOVERY

Type of hole . . . D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed . . . P = Packer, Cm = Cemented, Cb = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Otter Creek Study Site PROJECT . . . STATE Mont. SHEET 1 OF 3 HOLE NO DH74-104

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 3

FEATURE Otter Creek Study Site PROJECT . . . STATE Montana
DH HOLE NO 74-104 LOCATION * ALTIMETER GROUND ELEV 3204 DIP (ANGLE FROM HORIZ.) Vertical
COORDS. N . . . E . . .
BEGUN 9/23/74 FINISHED 10/2/74 DEPTH OF OVERBURDEN - TOTAL DEPTH 222.5 BEARING . . .
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 134.5' 10/2/74 LOGGED BY Taucher LOG REVIEWED BY . . .

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

Hole at 121.7' 9/26/74. 6" CS at 9.0'. W.L. at 93.0'. Hole squeezing below 80' Wash rods 80 to 121.7'. 2-3/4" core 121.7 to 151.4'

Hole at 151.4' 9/27/74. 6" CS at 9.0'. W.L. at 107.2'. Washed through 40' of cave & cuttings. 2-3/4" core 151.4 to 166.0'. Drilling delayed by wet field conditions.

Hole at 166.0' 9/30/74. 6" CS at 9.0'. W.L. at 130.0'. 2-3/4" core 166.0 to 189.2'. Last water at 170.7'. Added 1 bag of bentonite. W.L. at 127.5' end of shift. (No drill mud on probe)

Hole at 189.2' 10/1/74. 6" CS at 9.0'. W.L. at 134.8'. 2-3/4" core 189.2 to 212.5'. No drill water return. Hauled two loads of water.

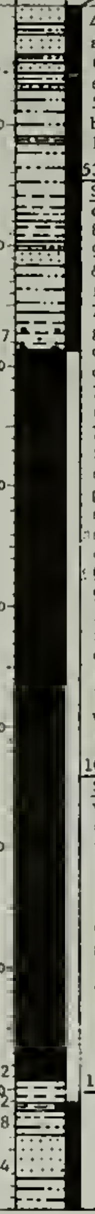
*490' W. & 1710' S. of NE Corner Sec. 26., T. 3 S., R. 45 E.

CORE RECOVERY (%): 100, 100, 100, 100, 100, 100, 100, 100, 100, 100, 100, 100, 100, 100, 100, 100, 100, 100, 100, 100, 100

PERCOLATION TESTS

Lab Sample G-49 106.0 to 111.7'
Lab Sample G-50 111.7 to 121.7'
Lab Sample G-51 121.7 to 128.7'
Lab Sample G-52 191.2 to 200.7'

ELEVATION (FEET)	DEPTH (FEET)
3098.3	105.
3075.3	128.7
3014.8	189.2
3012.8	191.2
3010.2	193.8
3006.6	197.4



CLASSIFICATION AND PHYSICAL CONDITION

47.8'; moderately cemented, fine grain sandstone 47.8 to 50.2'; siltstone 50.2 to 51.0'; silty, uncemented (pulverized) sandstone 51.0 to 51.4'; clayey siltstone 51.4 to 53.1'. Siltstone is firm & can be trimmed by knife; core lengths up to 1'.

53.1-105.7 SANDSTONE WITH SOME CLAYEY SILTSTONE ZONES: Light gray to tan & oxidized 57.5 to 57.8'; 78.0 to 80'; 83.5 to 83.7'; 93.7 to 93.9' & 97.9 to 98.4'; remaining material is light gray & unoxidized; moist; weakly cemented, friable, fine grain sandstone 53.1 to 77.5'; thin-bedded, uncemented, fine grain sandstone that begins to wash away during drilling 77.5 to 79.2'; weakly cemented, friable, fine grain sandstone 79.2 to 79.6'; uncemented, pulverized (like river sand), fine grain sandstone 79.6 to 89.5'; weakly cemented, friable, fine grain sandstone 89.5 to 93.2'; firm siltstone 93.2 to 94.2'; uncemented, pulverized (like river sand), fine grain sandstone 94.2 to 96.9'; firm, clayey siltstone 96.9 to 98.2'; firm, weakly cemented, friable, fine grain sandstone 98.2 to 99.0'; firm, clayey siltstone 99.0 to 99.8'; weakly cemented, friable, fine grain sandstone 99.8 to 101.7'; firm siltstone 101.7 to 102.5'; weakly cemented, friable, fine grain sandstone 102.5 to 104.0'; firm, clayey siltstone 104.0 to 104.7'; thin-bedded, non to weakly cemented, fine grain sandstone 104.7 to 105.7'; core lengths to 1½'.

105.7-128.7 CLAYEY SILTSTONE TO SILTY SHALE: Light gray; moist; material varies from clayey siltstone to silty shale; low to medium plasticity when reworked; incipient fissility; difficult trimming with knife; weakly cemented, friable, fine grain sandstone 106.7 to 107.0'; soft shale 111.0 to 111.3'; carbonaceous 116.6 to 116.7'; medium gray, firm shale that begins to air slack 118.0 to 119.6'; silty, thin-bedded, uncemented, friable sandstone 120.4 to 121.7'; silty shale 125.5 to 128.7'; slightly to moderately carbonaceous 127.0 to 128.7'.

128.7-189.2 COAL: Good core; core lengths 1 to 18"; vertical hairline fractures with fracture faces containing white (?) staining running length of core.

EXPLANATION

CORE LOSS
CORE RECOVERY

Type of hole . . . D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed . . . P = Packer, Cm = Cemented, Cb = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Otter Creek Study Site PROJECT . . . STATE Mont. SHEET 2 OF 3 HOLE NO. DH74-104

GEOLOGIC LOG OF DRILL HOLE

SHEET 3 OF 3

FEATURE Otter Creek Study Site PROJECT . . . STATE Montana
DH HOLE NO. 74-104 LOCATION * ALTIMETER GROUND ELEV. 3204 DIP (ANGLE FROM HORIZ.) Vertical
COORDS. N. . . E. . .
BEGUN 9/23/74 FINISHED 10/2/74 DEPTH OF OVERBURDEN . . . TOTAL DEPTH 222.5 BEARING . . .
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 134.5' 10/2/74 LOGGED BY Taucher LOG REVIEWED BY . . .

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

Hole at 212.5' 10/2/74. 6" CS at 9.0'. W.L. at 134.5'. 2-3/4" core 212.5 to 222.5'. Moved equipment to DH 74-105.

1/23/75. Moved rig & set up on DH74-104. Pulled 9.0 ft. of 6-in. CS.

Hole at 222.5' 1/24/75. 8" CS at 3.0'. Reamed (7⅞") hole 3.0 to 46.2'.

Hole at 222.5' 1/27/75. 8" CS at 3.0'. Drill mud at 20'. Reamed (7⅞") hole 46.2 to 140.7'.

Hole at 222.5' 1/28/75. 8" CS at 3.0'. Reamed (7⅞") hole 140.7 to 201.7'.

Hole at 222.5' 1/29/75. 8" CS at 3.0'. Installed 203.5' of 4" plastic pipe in hole (1.8' stickup). Pipe perforated 133.7 to 193.7'. Gravel (pea) packed around pipe. Bailed hole to 150'. Unable to bail below 150' as water entering hole equaled amount being bailed out. Pulled 8" CS.

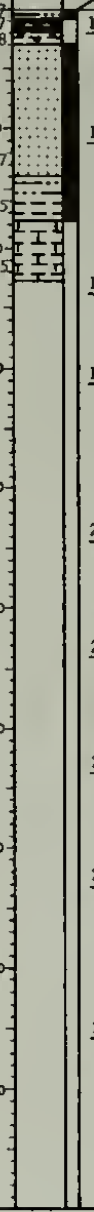
*490' W. & 1710' S. of NE Corner Sec. 26, T. 3 S., R. 45 E.

CORE RECOVERY (%): 100, 77, 80, 100, 93, 76

PERCOLATION TESTS

Lab Sample G-53 202.8 to 213.7'
Lab Sample G-54 213.7 to 217.5'

ELEVATION (FEET)	DEPTH (FEET)
3003.3	200.7
3002.3	201.7
3001.2	202.8
2990.3	213.7
2986.5	217.5
2981.5	222.5



CLASSIFICATION AND PHYSICAL CONDITION

189.2-191.2 CARBONACEOUS SHALE: Medium to dark gray; moist to wet; laminated; fissile; can be trimmed by knife; more carbonaceous with depth; 2 to 8" core lengths.

191.2-193.8 CLAYEY SILTSTONE: Light gray with medium to dark gray carbonaceous zone 191.2 to 191.6'; wet; low to medium plasticity when reworked; thin-bedded; can be trimmed by knife. Silty sandstone 191.2 to 191.5'; clayey to sandy siltstone 191.5 to 193.8'.

193.8-197.4 SILTY SANDSTONE: Light gray; wet; friable; fine grain; can be trimmed by knife; very weakly cemented; laminated; 2 to 12" core lengths.

197.4-200.7 SANDY TO CLAYEY SILTSTONE: Light gray; wet; sandy siltstone near top grading to clayey siltstone with depth; moderately plastic near bottom; laminated near top to thin-bedded near bottom; upper part is friable; can be trimmed by knife; 1 to 18" core lengths.

200.7-201.7 COAL & CARBONACEOUS SHALE: Dark gray to black; wet; carbonaceous shale 201.0 to 201.3'; remaining material is broken coal; shale is plastic and can be trimmed easily with knife.

201.7-202.8 CARBONACEOUS SHALE: Medium to dark gray; wet; moderately carbonaceous; plastic; cut by slickensides at various angles; thin-bedded; can be trimmed by knife; 1 to 3" core lengths.

202.8-213.7 SANDSTONE: Light gray; wet; fine grain; weakly cemented; friable; can be crushed between fingers; bedding not readily discernible; 1 to 3" core lengths.

213.7-217.5 CLAYEY SILTSTONE TO SILTY SHALE: Light gray; moist; massive; bedding not discernible; varies from clayey siltstone to silty shale; moderate to high plasticity; can be trimmed by knife with difficulty; 6 to 12" core lengths.

217.5-222.5 MARL: Light gray; moist; hard; cemented; can be scratched by knife; massive; 3 to 12" core lengths; bottom 12' left in hole.

EXPLANATION

CORE LOSS
CORE RECOVERY

Type of hole . . . D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed . . . P = Packer, Cm = Cemented, Cb = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Otter Creek Study Site PROJECT . . . STATE Mont. SHEET 3 OF 3 HOLE NO. DH74-104

Legend on Plate 9

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

OTTER CREEK STUDY SITE
OTTER CREEK COAL FIELD

GEOLOGIC LOG OF DH 74-104

DRAWN G.J. TAUCHER SUBMITTED
TRACED . . . RECOMMENDED G. K. Dirks
CHECKED . . . APPROVED

BILLINGS, MONTANA MARCH 1978
SHEETS 1 THROUGH 3 OF 3
1305-600-11

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 7

FEATURE Otter Creek Study Site PROJECT
HOLE NO DH 74-105 LOCATION * GROUND ELEV. Altimeter 3262
BEGUN 10/3/74 FINISHED 11/5/74 DEPTH OF OVERBURDEN 1.0 TOTAL DEPTH 413.8
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 225.0' 1/22/75 LOGGED BY Taucher

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

Hole started 10/3/74. NX drive samples 0 to 9.0'. 2-3/4" core 9.0 to 30.3'. 5" CS set to 13.6'.

10/4/74 Heavy rain. No work.

Hole at 30.3' 10/7/74. 5" CS at 13.6'. Hole dry. 2-3/4" core 30.3 to 70.2'.

Hole at 70.2' 10/8/74. 5" CS at 13.6'. W.L. at 26.5'. 2-3/4" core 70.2 to 100.7'.

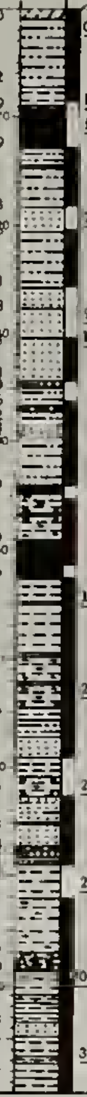
*125' W. & 610' N. of SE corner, Sec. 34, T. 3 S., R. 45 E.

CORE RECOVERY (%): 100, 100, 78, 100, 75, 100, 82, 100, 100, 100, 100, 100, 100, 100, 100, 100, 100, 100, 100, 100, 100, 100, 100

SAMPLES

- Lab Sample G-55 0 to 8.6'
- Lab Sample G-56 12.9 to 18.3'
- Lab Sample G-57 20.6 to 25.8'
- Lab Sample G-58 30.4 to 34.3'
- Lab Sample G-59 36.3 to 44.0'
- Lab Sample G-60 45.3 to 51.3'
- Lab Sample G-61 52.6 to 59.8'
- Lab Sample G-62 59.8 to 65.2'
- Lab Sample G-63 65.2 to 69.1'
- Lab Sample G-64 72.7 to 79.0'
- Lab Sample G-65 82.1 to 93.3'
- Lab Sample G-66 93.3 to 103.0'

ELEVATION (FEET)	DEPTH (FEET)
3261.0	1.0
3254.8	7.2
3252.1	9.9
3249.1	12.9
3248.7	18.3
3241.4	20.6
3236.2	25.8
3234.2	27.8
3231.7	30.3
3227.7	34.3
3227.0	35.0
3225.4	36.6
3224.8	37.2
[illegible]	[illegible]
3222.5	39.5
3218.0	44.0
3213.0	49.0
3209.4	52.6
3196.4	65.6
3192.9	69.1
3189.3	72.7
3186.7	75.3
3184.6	77.4
3184.2	77.8
3183.0	79.0
3179.9	82.1
3175.0	87.0
3173.1	88.9
3168.7	93.3
3167.2	94.8
3163.3	98.7



CLASSIFICATION AND PHYSICAL CONDITION

0-1.0 SILTY CLAY: Tan; oxidized; dry; few roots; approx. 35% very fine sand; approx. 65% low plasticity fines (ML-CL to CL).

FT. UNION FORMATION - TERTIARY

1.0-7.2 CLAYEY SILTSTONE: Tan; oxidized; moist; soft; weathered; gypsum inclusions throughout; low plasticity; cuts easily with knife; ¼" to 3" core lengths; sandy 4.5 to 5.5'.

7.2-9.9 SHALE CARBONACEOUS SHALE & COAL: Tan & oxidized 7.7 to 9.0'. Dark gray & carbonaceous 9.0 to 9.9' with coal bed 9.3 to 9.6'; moist; shale is plastic & trims easily with knife.

9.9-12.9 COAL: Moist; badly broken.

12.9-18.3 CLAYEY TO SANDY SILTSTONE: Light gray 12.9 to 14.6'; dark gray & carbonaceous 14.6 to 14.8'; light gray with several, tan, oxidized zones 14.8 to 17.6'; tan & oxidized 17.6 to 18.3'; moist; soft to firm; crumbles between fingers in sandy zones; trims easily with knife in clayey zones; clayey to sandy siltstone 12.9 to 14.6'; carbonaceous shale 14.6 to 14.8'; friable, sandy siltstone 14.8 to 16.0'; firm, clayey siltstone 16.0 to 17.6'; friable, sandy siltstone 17.6 to 18.3'; core lengths 3 to 12".

18.3-20.6 SANDSTONE: Tan & oxidized 18.3 to 18.8' & 20.1 to 20.6'; light gray 18.8 to 20.1'; hard; cemented; silty; very fine grain; massive; can be scratched by knife; 3 to 18" core lengths.

20.6-25.8' SILTSTONE: Tan; oxidized; moist; friable; cuts easily with knife; few clayey & sandy, siltstone stringers; bedding not readily discernible; 3" maximum core length.

25.8-27.8 SANDSTONE: Tan to light gray; slightly oxidized; moist; thin-bedded; fine grain; silty; weakly cemented; crushes with difficulty between fingers; 1 to 3" core lengths.

27.8-30.3 SANDSTONE: Light gray; dry; cemented; very hard; can be scratched with knife; silty; very fine grain; massive; 90° oxidized joint 27.8 to 30.3'; 6 to 12" core lengths.

30.3-34.3 SANDSTONE: Gray to tan; moist; fine grain; moderately cemented & hard 30.3 to 33.3'; weakly cemented 33.3 to 34.3'; 1 to 12" core lengths.

34.3-35.0 CLAYEY SILTSTONE: Tan to gray; some oxidation; moist; can be trimmed by knife; moderately plastic; firm.

EXPLANATION

CORE LOSS
CORE RECOVERY

Type of hole . . . D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Otter Creek Study Site PROJECT STATE Montana SHEET 1 OF 7 HOLE NO DH74-105

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 7

FEATURE Otter Creek Study Site PROJECT
HOLE NO DH 74-105 LOCATION * GROUND ELEV. Altimeter 3262
BEGUN 10/3/74 FINISHED 11/5/74 DEPTH OF OVERBURDEN 1.0 TOTAL DEPTH 413.8
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 225.0' 1/22/75 LOGGED BY Taucher

Hole at 100.7' 10/9/74. 5" CS at 13.6'. W.L. at 96.0'. 2-3/4" core 100.7 to 134.3'.

Hole at 134.3' 10/10/74. 5" CS at 13.6'. W.L. at 26.0'. 2-3/4" core 134.3 to 157.6'.

Hole at 157.6' 10/11/74. 5" CS at 13.6'. W.L. at 26.0'. 2-3/4" core 157.6 to 182.3'. Driller reported hole clean at start of shift.

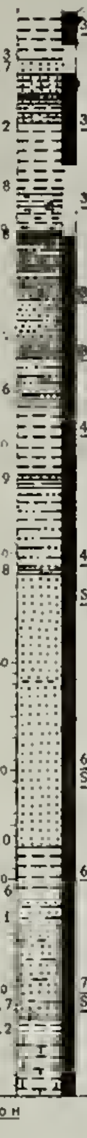
Hole at 182.3' 10/15/74. 5" CS at 13.6'. W.L. at 50.0'. Washed through 60' of cave & cuttings. 2-3/4" Core 182.3 to 207.3'.

* 125' W. & 610' N. of SE corner Sec. 34, T. 3 S., R. 45 E.

CORE RECOVERY (%): 100, 100, 100, 100, 100, 100, 84, 100, 79, 100, 100, 100, 100, 100, 100, 100, 100, 100, 100, 100, 100, 91, 100, 100, 100

- Lab Sample G-67 105.7 to 114.1'
- Lab Sample G-68 120.7 to 128.0'
- Lab Sample G-69 128.0 to 135.6'
- Lab Sample G-70 135.6 to 143.9'
- Lab Sample G-71 143.9 to 151.8'
- Lab Sample G-72 151.8 to 177.0'
- Lab Sample G-73 177.0 to 181.6'
- Lab Sample G-74 181.6 to 192.7'
- Lab Sample G-75 192.7 to 201.0'

ELEVATION (FEET)	DEPTH (FEET)
3157.7	104.3
3156.3	105.7
3151.8	110.2
3144.2	117.8
3141.2	120.8
3126.4	135.6
3118.1	143.9
3110.2	151.8
3085.0	177.0
3080.4	181.6
3077.9	184.1
3069.3	192.7
3067.8	194.2



35.0-36.6 SILTSTONE: Gray; dry to moist; very hard and cemented; can be scratched by knife; broken (1 to 2") 35.0 to 35.3' and 35.9 to 36.6'; 90° oxidized, partly cemented joint 35.3 to 35.9'.

36.6-37.2 SHALE: Gray, moist; thin-bedded; plastic; trims easily with knife; incipient fissility; becoming slightly carbonaceous with depth.

37.2-38.3 CLAYEY TO SANDY SILTSTONE: Gray; moist; thin-bedded; trims easily with knife; clayey near top; sandy near bottom; friable near bottom; 1 to 6" core lengths.

38.3-39.5 SILTY SANDSTONE: Light gray; moist; friable; uncemented; silty; fine grain; 3" core lengths.

39.5-44.0 CLAYEY SILTSTONE: Light gray; moist; thin-bedded to almost massive; moderately plastic; trims easily with knife; 4 to 18" core lengths.

44.0-49.0 CARBONACEOUS SHALE & COAL: Medium to dark gray; moist; plastic; trims easily with knife; thin-bedded to laminated; slightly to moderately carbonaceous; could be bentonitic; coal 44.2 to 44.6' and 46.6 to 46.9'; 1 to 6" core lengths.

49.0-52.6 COAL: Chips to 1" fragments; plastic, carbonaceous shale 52.4 to 52.6'.

52.6-65.6 SHALE: Medium to light gray 52.6 to 59.8' and 64.7 to 65.6'. Dark gray and slightly carbonaceous 59.8 to 64.7'; firm; plastic; moist; could be bentonitic; trims easily with knife; air slacks; 1 to 2" cemented, marl concretions (?) 54.8 to 54.9', 59.6 to 59.8' and 62.2 to 62.4' few gypsum crystals; core lengths up to 1'.

65.6-69.1 SANDY SILTSTONE TO SILTY SANDSTONE: Light gray; moist; can be trimmed by knife; uncemented; friable; sandy siltstone 65.6 to 67.2'; silty sandstone 67.2 to 69.1'; bedding not readily discernible; core lengths 4 to 12".

69.1 to 72.7 SHALE: Light gray 69.1 to 71.0'; medium to dark gray and slightly carbonaceous 71.0 to 72.7'; moist; firm; plastic; can be trimmed by knife; air slacks; almost fissile; core lengths 2 to 18".

72.7-75.3 SILTY SANDSTONE TO SANDY SILTSTONE: Gray; moist; firm; thin-bedded; weakly cemented; can be crushed between fingers with difficulty; alternating lenses of silty sandstone and sandy siltstone; three, 1 to 3" cemented concretions 74.0 to 74.6'; plastic shale 75.1 to 75.3'; 3 to 8" core lengths.

EXPLANATION

CORE LOSS
CORE RECOVERY

Type of hole . . . D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Otter Creek Study Site PROJECT STATE Montana SHEET 2 OF 7 HOLE NO DH74-105

GEOLOGIC LOG OF DRILL HOLE

SHEET 3 OF 7

FEATURE Otter Creek Study Site PROJECT
HOLE NO DH 74-105 LOCATION * GROUND ELEV. Altimeter 3262 DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 10/3/74 FINISHED 11/5/74 DEPTH OF OVERBURDEN 1.0 TOTAL DEPTH 413.8 BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 225.0' 1/22/75 LOGGED BY Taucher LOG REVIEWED BY

Hole at 207.3' 10/16/74. 5" CS at 13.6'. W.L. at 44.6'. Driller reported clean hole at start of shift. 2-3/4" core 207.3 to 241.3'. Lost all drill water at 238'. Hole dry at end of shift.

Hole at 241.3' 10/17/74. 5" CS at 13.6'. W. L. at 210.7'. 2-3/4" core 241.3 to 242.3'. Tried sealing hole with drill mud (4 sacks). Lost all mud set NXCS to 242.3'. NX core 242.3 to 249.3'.

Hole at 249.3' 10/18/74. 5" CS at 13.6'. NXCS at 242.3'. W.L. at 99.0'. NX core 249.3 to 273.0'. NXCS set to 244.0'. Losing very little water last run.

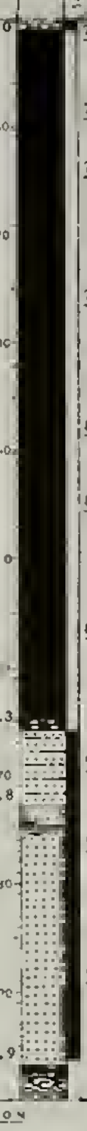
Hole at 273.0' 10/21/74. 5" CS at 13.6'. NXCS at 242.3'. W.L. at 213.0'. NX core 273.0 to 286.0'. Lost all drill water. Pulled NXCS.

*125' W. & 610' N. of SE Corner Sec. 34, T. 3 S., R. 45 E.

CORE RECOVERY (%): 100, 10, 100, 100, 100, 100, 100, 100, 100, 100, 100, [illegible], [illegible], 91, 100, [illegible], 100, 96

- Lab Sample G-76 266.0 to 296.0'

ELEVATION (FEET)	DEPTH (FEET)
3061.0	201.0
2996.7	265.3
2989.2	272.8
2965.1	296.9



CLASSIFICATION AND PHYSICAL CONDITION

75.3-77.4 SANDSTONE: Light gray; moist; very fine grain; weakly cemented; friable; bedding not readily discernible; 6 to 12" core lengths.

77.4-77.8 SILTY SHALE: Medium gray; moist; firm; moderately plastic; can be trimmed by knife; 2" core lengths.

77.8-79.0 SANDY SILTSTONE: Light gray; moist; very hard and cemented 77.8 to 78.2' (can be scratched by knife); laminated, friable, uncemented, sandy siltstone 78.2 to 79.0'; few plastic, shale lenses below 78.2'; 1 to 6" core lengths.

79.0-82.1 SILTY SHALE: Medium gray; moist; firm to very firm with zones in lower part being cemented with calcium carbonate; can be trimmed by knife with difficulty; plastic when reworked; bedding not readily discernible; 1 to 12" core lengths.

82.1-87.0 SHALE: Medium gray; moist; trims easily with knife; plastic; air slacks; almost fissile; slightly carbonaceous; 6 to 24" core lengths.

87.0-88.9 SILTY SHALE: Medium gray to black; moist; firm; can be trimmed by knife; plastic; carbonaceous; 1/8 to 1½" wide, 60 to 70°, coal dike 87.0 to 88.7'; coal 88.7 to 88.9' (coal may have squeezed into open fractures); 3 to 12" core lengths.

88.9-93.3 SHALE & SILTY SHALE: Medium gray; moist; can be trimmed by knife 88.9 to 91.0'; cemented, marl concretion 91.0 to 91.8'; soft shale 91.8 to 92.8'; firm, silty shale 92.8 to 93.3'; plastic when reworked; 70° fracture 92.8 to 93.3'; 3 to 6" core lengths.

93.3-94.8 SILTY SANDSTONE: Light gray; moist; uncemented but firm; friable; very silty with clay zone 94.2 to 94.5'; 1 to 6" core lengths.

94.8-98.7 SHALE: Medium gray; moist; alternating zones of soft to firm shale; silty in upper part; hard, calcareous shale 96.7 to 97.2' air slacks slightly; almost fissile in zones; easy to difficult trimming with knife; 2 to 6" core lengths.

98.7-104.3 SHALE & SILTY SHALE: Medium gray; moist; firm; can be trimmed by knife; silty shale 98.7 to 99.9'; soft shale 99.9 to 100.7'; silty shale 100.7' to 103.1'; shale 103.1 to 104.3'; moderately to highly plastic when worked; air slacks in more plastic zones; 6 to 12" core lengths.

EXPLANATION

CORE LOSS
CORE RECOVERY

Type of hole . . . D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Otter Creek Study Site PROJECT STATE Montana SHEET 3 OF 7 HOLE NO DH74-105

GEOLOGIC LOG OF DRILL HOLE

SHEET 4 OF 7

FEATURE Otter Creek Study Site PROJECT STATE Montana
HOLE NO DH 74-105 LOCATION * COORDS. N. E. GROUND ELEV. Altimeter 3262 DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 10/3/74 FINISHED 11/5/74 DEPTH OF OVERBURDEN 1.0 TOTAL DEPTH 413.8 BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 225.0' 1/22/75 LOGGED BY Taucher LOG REVIEWED BY

Hole at 286.0' 10/22/74. 5" CS at 13.6'. No W.L. reading. Cave at 95'. Reamed hole 244.0 to 286.0'. Set NXCS to 286.5'. Washed out hole. NX core 286.0 to 290.0'. No drill water loss.

Hole at 290.0' 10/23/74. 5" CS at 13.6'. NXCS at 286.5'. W.L. at 78.0'. NX core 290.0 to 314.2'.

Hole at 314.2' 10/24/74. 5" CS at 13.6'. NXCS at 286.5'. W.L. at 124.0'. NX core 314.2 to 316.9'. Repairs on equipment. 3 hrs. travel time to Billings.

10/25/74 no drilling. Drill crew reported to Billings for physical and drivers exam.

Hole at 316.9' 10/29/74. 5" CS at 13.6'. NXCS at 286.5'. W.L. at 186.0'. NX core 316.9 to 356.0'. Sand running in hole.

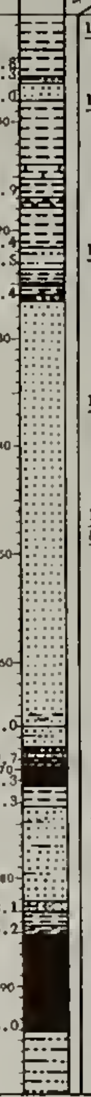
Hole at 356.0' 10/30/74. 5" CS at 13.6'. NXCS at 286.5'. W.L. at 226.0'. NX core 356.0 to 385.2'. Sand running in hole. Washed in barrel between runs.

10/31 and 11/1/74 - Muddy field conditions. Unable to drill.

*125' W. & 610' N. of SE Corner Sec. 34, T. 3 S., R. 45 E.

CORE RECOVERY (%): 75, 80, 100, 100, 100, 100, 100, 89, 90, 100, 97

ELEVATION (FEET)	DEPTH (FEET)
2956.2	305.8
2955.7	306.3
2954.0	308.0
2945.1	316.9
2940.6	321.4
2938.5	323.5
2935.6	326.4
2896.0	366.0
2892.3	369.7
2890.7	371.3
2888.7	373.3
2878.9	383.1
2876.8	385.2
2868.0	394.0



CLASSIFICATION AND PHYSICAL CONDITION

104.3-105.7 SANDSTONE: Light gray; moist; silty; laminated to thin-bedded; fine grain; very weakly cemented; friable; core lengths 2 to 8".

105.7-110.2 SILTY SHALE: Light to medium gray; moist; can be trimmed by knife; almost fissile; alternating laminations of silty shale & silty sandstone 105.7 to 107.5' & 109.2 to 110.2'; soft sandstone 108.2 to 108.4'; remaining material is silty shale; moderately plastic when worked; 6 to 12" core lengths.

110.2-117.8 SILTY SHALE & SHALE: Medium gray; moist; firm; difficult trimming with knife; plastic when reworked; begins to air slack; bottom 1' is slightly carbonaceous & more plastic; bedding not readily discernible; 80° joint 114.7 to 115.5'; 3 to 18" core lengths.

117.8-120.8 CARBONACEOUS SHALE & COAL: Black, plastic, carbonaceous shale 117.8 to 120.2'; coal 120.2 to 120.8'; almost fissile; trims with knife; air slacks; 80° joint 117.8 to 119.0'; 1 to 8" core lengths.

120.8-135.6 CLAYEY TO SANDY SILTSTONE & SANDSTONE: Light gray; moist; siltstone is firm, uncemented & can be trimmed by knife; sandstone is fine grain, silty & friable; clayey siltstone 120.8 to 122.6'; silty sandstone 122.6 to 123.5'; clayey to sandy siltstone 123.5 to 125.0'; cemented, very hard, calcareous siltstone 125.0 to 125.8'; sandy siltstone with sandstone laminations 125.8 to 130.2'; silty sandstone 130.2 to 131.2'; sandy to clayey siltstone 131.2 to 134.6'; silty sandstone 134.6 to 135.0'; clayey siltstone 135.0 to 135.6'; 2 to 12" core lengths.

135.6-143.9 SHALE & SILTY SHALE: Medium gray; moist; firm; can be trimmed by knife; almost fissile in zones; thin-bedded to almost massive; air slacks; few, 1" calcium carbonate cemented, siltstone concretions; uncemented, fine grain sandstone 142.7 to 143.0'.

143.9-151.8 CLAYEY TO SANDY SILTSTONE: Light to medium gray; moist; firm; upper part is alternating shale and siltstone laminations; lower part is laminated siltstone with occasional shale partings; clayey zones are moderately plastic; lower part can be crushed between fingers with difficulty; trims easily with knife; Calcareous

EXPLANATION

CORE LOSS
CORE RECOVERY

Type of hole . . . D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Otter Creek PROJECT STATE Montana SHEET 4 OF 7 HOLE NO DH74-105

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

OTTER CREEK STUDY SITE
OTTER CREEK COAL FIELD

GEOLOGIC LOG OF DH74-105

DRAWN G.J. TAUCHER SUBMITTED [illegible]
TRACED RECOMMENDED H. R. DeKee
CHECKED APPROVED [illegible]

BILLINGS, MONTANA MARCH 1976
SHEETS 1 THROUGH 4 OF 7
1305-600-12

Legend on Plate 9

PLATE 15

GEOLOGIC LOG OF DRILL HOLE

SHEET 5 OF 7

FEATURE Otter Creek Study Site PROJECT Altimeter STATE Montana
DH HOLE NO 74-105 LOCATION * GROUND ELEV 3262 DIP (ANGLE FROM HORIZ.) Vertical
COORDS. N. E.
BEGUN 10/3/74 FINISHED 11/5/74 DEPTH OF OVERBURDEN 1.0 TOTAL DEPTH 413.8 BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 225.0' 1/22/75 LOGGED BY Taucher LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

Hole at 385.2' 11/4/74. 5" CS at 13.6'. NXCS at 286.5'. W.L. at 222.5'. NX core 385.2 to 413.8'. Washed away most of core from 395.2 to 402.8' due to core blocking.

Hole at 413.8' 11/5/74. 5" CS at 13.6'. NXCS at 286.5'. W.L. at 216.0'. Pulled NXCS and 5" CS. Set 3.0' of 6" CS in hole. Moved rig to DH74-106. Hole completed to 413.8'.

12/18/74. Moved rig to DH74-105. Set 8" CS to 3'.

Hole at 413.8' 1/7/75. 8" CS at 3.0'. Reamed hole with 7-7/8" rock bit 0 to 43.0'

Hole at 413.8' 1/8/75. 8" CS at 3.0'. Reamed (7½") hole 43.0 to 130.0'

Hole at 413.8' 1/9/75. 8" CS at 3.0'. Reamed (7½") hole 130.0 to 190.0' Lost all return at 179.0'. Pumped 3 pits of mud into hole. No circulation.

*125' W. & 610' N. of SE Corner Sec. 34, T. 3 S., R. 45 E.

CORE RECOVERY (%): 33, 88, 72

ELEVATION (FEET) / DEPTH (FEET): 2855.6 / 406.4; 2848.2 / 418.8

CLASSIFICATION AND PHYSICAL CONDITION

cemented concretion 151.2 to 151.4'; 1 to 14" core lengths.

151.8-177.0 SANDSTONE: Light gray; moist; compact; fine grain; friable (crushes easily between fingers); non to very weakly cemented; uncemented (like river sand) 154.6 to 156.0', 162.6 to 164.6' & 173.5 to 174.4'; remaining material trims easily with knife; few thin carbonaceous streaks 161.8 to 162.0'; ½" coal filled 10 to 30° fracture (?) at 177.8'; 70° fresh fracture 172.6 to 173.0'; maximum core length 1'.

177.0-181.6 SHALE: Medium gray; moist; firm; very plastic; could be bentonitic; trims easily with knife; air slacks; broken on 1 to 2" centers along horizontal to 70° fractures; thin bedded.

181.6-184.1 SANDY SHALE OR SHALEY SANDSTONE: Alternating light gray, fine grain sandstone & medium gray shale laminations; moist; moderately plastic when reworked; can be trimmed by knife; crushes between fingers with difficulty; 1 to 12" core lengths.

184.1-197.7 SHALEY SANDSTONE: Light gray, fine grain silty sandstone with some laminations & thin beds of plastic medium gray shale; weakly cemented; difficult crushing between fingers; moist; trims with knife; few thin (-1/8") carbonaceous bedding planes; laminated to thin-bedded; very shaley 183.3 to 184.1' & 187.2 to 187.8'; 1 to 12" core lengths.

192.7-194.2 SHALE: Medium to dark gray; moist; plastic; could be bentonitic; slightly carbonaceous; cuts easily with knife; air slacks; few sand laminations near middle; 2 to 4" core lengths.

194.2-201.0 MARL & CALCAREOUS SHALE: Light to medium gray; hard; very hard 194.2 to 197.7'; moist; trims with difficulty by knife; thin-bedded to laminated; fissile; carbonaceous 200.2 to 201.0'; 2 to 12" core lengths.

201.0-265.3 COAL: Black, moist; broken in chips to 6" core lengths; cut by horizontal & vertical hairline fractures (some with white staining); air slacks; shaley 264.9 to 265.3'.

265.3-272.8 SANDY SILTSTONE: Approaching silty sandstone; light gray; moist; laminated; can be trimmed by knife; very fine, uniform sand; trace of clay; scattered carbonaceous fragments; slightly carbonaceous silty shale 265.3 to

EXPLANATION

CORE LOSS
CORE RECOVERY

Type of hole . . . O = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Otter Creek Study Site PROJECT STATE Montana SHEET 5 OF 7 HOLE NO. DH74-105

GEOLOGIC LOG OF DRILL HOLE

SHEET 6 OF 7

FEATURE Otter Creek Study Site PROJECT STATE Montana
DH HOLE NO 74-105 LOCATION * Altimeter GROUND ELEV 3262 DIP (ANGLE FROM HORIZ.) Vertical
COORDS. N. E.
BEGUN 19/3/74 FINISHED 11/5/74 DEPTH OF OVERBURDEN 1.0 TOTAL DEPTH 413.8 BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 225.0' 1/22/75 LOGGED BY Taucher LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

Hole at 413.8' 1/10/75. 8" CS at 3.0'. Pumped Bentonite into hole until circulation was resumed. Reamed (7½") hole 190.0 to 215.0'. Lost all circulation at 210.0'.

Hole at 413.8' 1/13/75. 8" CS at 3.0'. Drill mud at 81'. Pumped in 7 pits of drill mud to recover circulation. Reamed (7½") hole 215.0 to 222.0' Dropped 60' of drill rods in hole.

Hole at 413.8' 1/14/75. 8" CS at 3.0'. Drill mud at 50'. Fished for drill rods.

Hole at 413.8' 1/15/75. 8" CS at 3.0'. Drill mud at 61'. Fished for & recovered 60' of drill rods. Reamed (7½") hole 222.0 to 237.0'.

Hole at 413.8' 1/16/75. 8" CS at 3.0'. Reamed (7½") hole 237.0 to 301.0'

Hole at 413.8' 1/17/75. 8" CS at 3.0'. Drill mud at 30.0'. Pumped in drill mud to get back circulation. Reamed (7½") hole 301.0 to 311.0'. Lost circulation at 311.0'. Pulled rods.

*125' W. & 610' N. of SE Corner Sec. 34, T. 3 S., R. 45 E.

CLASSIFICATION AND PHYSICAL CONDITION

265.8'; can be crushed with difficulty between fingers; core lengths 1 to 8".

272.8-296.9 SILTY SANDSTONE: Light gray; moist; very weakly cemented; can be crushed between fingers with difficulty; fine grain; uncemented (like river sand) 287.0 to 290.0'; core begins to wash away during drilling in places; few 1/8 to 1/2" coal streaks 274.0 to 275.5'; clayey sandstone 273.0 to 273.5'; core lengths 1 to 18".

296.9-305.8 CARBONACEOUS SHALE: Medium to dark gray; moist; firm; can be trimmed with knife; plastic; thin bedded to laminated; coal & carbonaceous shale 296.9 to 297.3' with associated 45° slickensides; highly carbonaceous 298.0 to 299.3' & 303.2 to 303.3'; core lengths ½ to 6".

305.8-306.3 SILTSTONE: Light gray; moist; firm; can be trimmed with knife; clayey & sandy; low plasticity; 1 to 2" core lengths.

306.3-308.0 SILTY SANDSTONE: Light gray; moist; fine grain; weakly cemented; can be trimmed by knife; difficult crushing between fingers; 1 to 12" core lengths.

308.0-316.9 SILTY SHALE: Light to medium gray; moist; firm; laminated to thin bedded; air slacks; fissile; can be trimmed with knife; marl or calcareous shale 313.8 to 315.2'; core lengths 1 to 6".

316.9-321.4 SILTY SHALE & CARBONACEOUS SHALE: Medium to dark gray carbonaceous shale 316.9 to 317.9'; medium gray silty shale 317.9 to 321.4'; cuts easily with knife; thin bedded; air slacks; fissile; moderately plastic; 1 to 6" core lengths.

321.4-323.5 CLAYEY SILTSTONE: Light gray; moist; laminated to thin bedded; low plasticity; some fine sand; can be trimmed by knife; 3 to 6" core lengths.

323.5-326.4 SHALE, CARBONACEOUS SHALE & COAL: Light gray silty shale 323.5 to 324.8'; carbonaceous shale 324.8 to 326.0' with coal 324.8 to 325.3'; light gray clayey siltstone 326.0 to 326.4'; shale is moderately plastic, air slacks & can be trimmed by knife; siltstone is soft & crumbled; core lengths ½ to 12".

326.4-366.0 SANDSTONE: Light gray; moist; fine grain; uncemented (like river sand); compact; slightly carbonaceous 364.8 to 365.5'; weakly cemented

EXPLANATION

CORE LOSS
CORE RECOVERY

Type of hole . . . D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Otter Creek Study Site PROJECT STATE Montana SHEET 6 OF 7 HOLE NO DH74-105

GEOLOGIC LOG OF DRILL HOLE

SHEET 7 OF 7

FEATURE Otter Creek Study Site PROJECT STATE Montana
DH HOLE NO 74-105 LOCATION * Altimeter GROUND ELEV 3262 DIP (ANGLE FROM HORIZ.) Vertical
COORDS. N. E.
BEGUN 10/3/74 FINISHED 11/5/74 DEPTH OF OVERBURDEN 1.0 TOTAL DEPTH 413.8 BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 225.0' 1/22/75 LOGGED BY Taucher LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

1/20/75 - U.S.G.S. logging hole

Hole at 413.8' 1/21/75. 8" CS at 3.0'. Drill mud at 20'. Washed hole to 413.8'. Set 305' of plastic pipe in hole (includes 2' stickup). Pipe perforated 203.0 to 263.0'. Packer rubber at 268.0'.

Hole at 413.8' 1/22/75. 305' of 4" plastic pipe in hole, 8" CS at 3.0' Gravel (pea) packed hole around 4" pipe. Bailed hole down to 245'. Unable to bail below this depth as flow into hole equaled water bailed out. Pulled 8" CS.

1/23/75 W.L. at 221.0'

*125' W. & 610' N. of SE Corner Sec. 34, T. 3 S., R. 45 E.

CLASSIFICATION AND PHYSICAL CONDITION

326.4 to 326.8'; crumbles easily between fingers.

366.0-369.7 SILTY SANDSTONE & SILTY SHALE: Light to medium gray; moist; firm; can be trimmed by knife; sandstone is friable & silty; shale is moderately plastic; top part is mostly laminated silty sandstone; bottom part is laminations of silty sandstone & silty shale with several carbonaceous streaks; 2 to 12" core lengths.

369.7-371.3 COAL: Cut by vertical & horizontal hairline fractures.

371.3-373.3 SILTY SHALE: Light gray; moist; firm; bedding not readily discernible; can be trimmed by knife 371.3-372.3'; hard cemented marl (?) that can be scratched by knife 372.3 to 373.3'; 2 to 12" core lengths.

373.3-383.1 SILTY SANDSTONE: Light gray; moist; compact; fine grain; weakly cemented; laminated; friable; sandy siltstone 382.1 to 383.1'; core begins washing away during drilling; core lengths 1/8 to 2".

383.1-385.2 SILTY SHALE: Light gray 383.1 to 384.4'; medium to dark gray & carbonaceous 384.4 to 385.2'; moderately plastic; air slacks; thin bedded to laminated; can be trimmed by knife; 1 to 12" core lengths.

385.2-394.0 COAL: Air slacks; cut by vertical & horizontal hairline fractures; 3 to 6" core lengths.

394.0-406.4 CLAYEY SILTSTONE: Light gray; moist; firm to moderately hard; can be trimmed by knife; will not crush between fingers; low plasticity when reworked; 1 to 6" core lengths.

406.4-413.8 SILTY SHALE: Light gray moist; firm; trims by knife with difficulty; begins to air slack; broken along bedding planes on ½ to 6" centers; broken along 90° fracture in cemented siltstone & sandstone 409.4 to 410.6'.

EXPLANATION

CORE LOSS
CORE RECOVERY

Type of hole . . . O = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Otter Creek Study Site PROJECT STATE Montana SHEET 7 OF 7 HOLE NO DH74-105

Legend on Plate 9

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

OTTER CREEK STUDY SITE
OTTER CREEK COAL FIELD

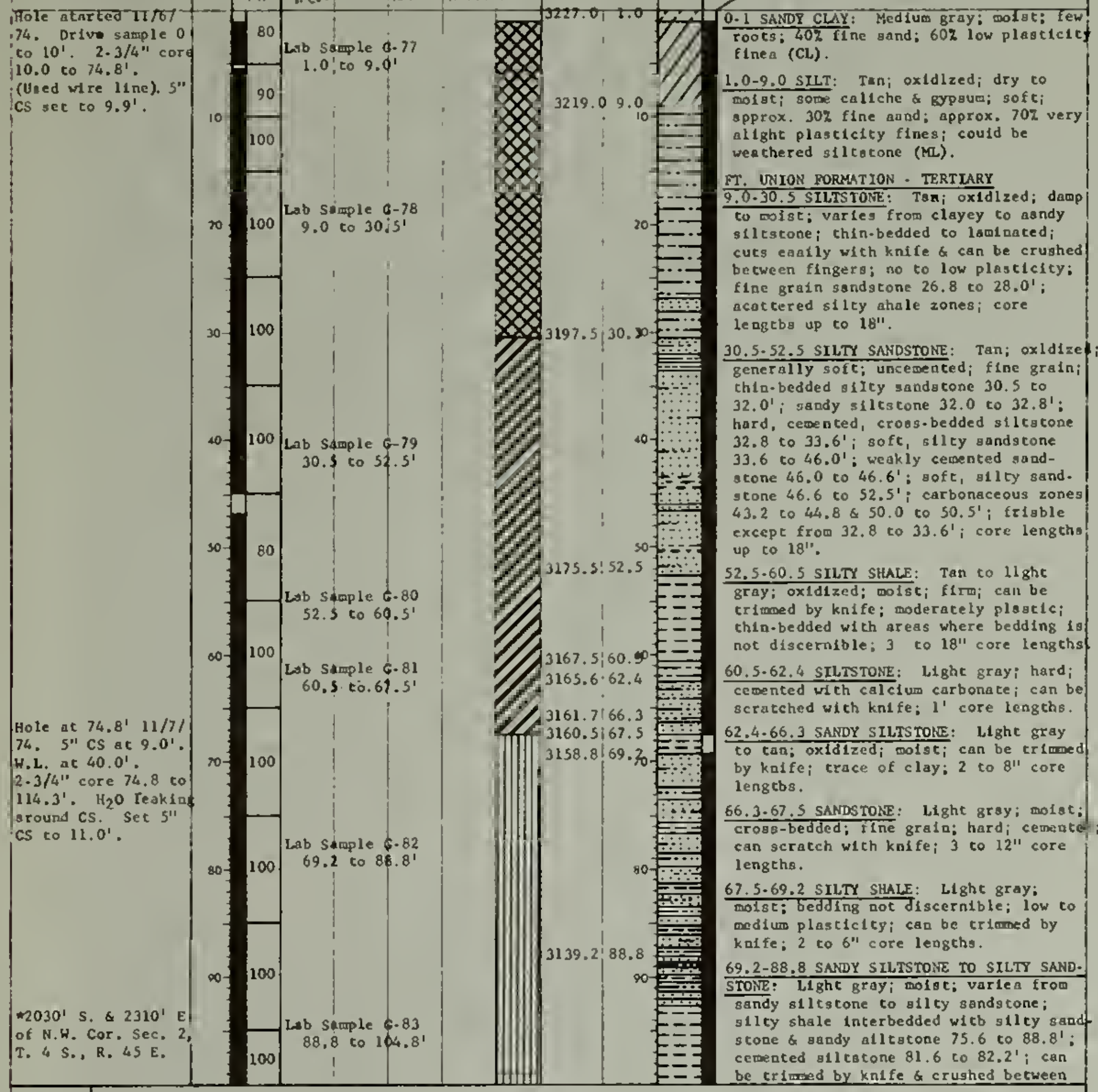
GEOLOGIC LOG OF DH74-105

DRAWN G.J. TAUCHER SUBMITTED
TRACED RECOMMENDED
CHECKED APPROVED
BILLINGS, MONTANA SHEETS 5 THROUGH 7 OF 7 MARCH 1975 1305-600-13

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 3

FEATURE Otter Creek Study Site PROJECT STATE Montana
DH HOLE NO 74-106 LOCATION * COORDS N. E. Altimeter GROUND ELEV 3228 DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 11/6/74 FINISHED 12/2/74 DEPTH OF OVERBURDEN 9.0 TOTAL DEPTH 247.6 BEARING --
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 158.1' 1/22/75 LOGGED BY Taucher LOG REVIEWED BY



Hole started 11/6/74. Drive sample 0 to 10'. 2-3/4" core 10.0 to 74.8'. (Used wire line). 5" CS set to 9.9'.

Hole at 74.8' 11/7/74. 5" CS at 9.0'. W.L. at 40.0'. 2-3/4" core 74.8 to 114.3'. H_2O leaking around CS. Set 5" CS to 11.0'.

*2030' S. & 2310' E of N.W. Cor. Sec. 2, T. 4 S., R. 45 E.

Lab Sample G-77 1.0 to 9.0'
Lab Sample G-78 9.0 to 30.5'
Lab Sample G-79 30.5 to 52.5'
Lab Sample G-80 52.5 to 60.5'
Lab Sample G-81 60.5 to 67.5'
Lab Sample G-82 69.2 to 88.8'
Lab Sample G-83 88.8 to 104.8'

ELEVATION (FEET)	DEPTH (FEET)
3227.0	1.0
3219.0	9.0
3197.5	30.5
3175.5	52.5
3167.5	60.5
3165.6	62.4
3161.7	66.3
3160.5	67.5
3158.8	69.2
3139.2	88.8

0-1 SANDY CLAY: Medium gray; moist; few roots; 40% fine sand; 60% low plasticity fines (CL).

1.0-9.0 SILT: Tan; oxidized; dry to moist; some caliche & gypsum; soft; approx. 30% fine sand; approx. 70% very slight plasticity fines; could be weathered siltstone (ML).

FT. UNION FORMATION - TERTIARY

9.0-30.5 SILTSTONE: Tan; oxidized; damp to moist; varies from clayey to sandy siltstone; thin-bedded to laminated; cuts easily with knife & can be crushed between fingers; no to low plasticity; fine grain sandstone 26.8 to 28.0'; scattered silty shale zones; core lengths up to 18".

30.5-52.5 SILTY SANDSTONE: Tan; oxidized; generally soft; uncemented; fine grain; thin-bedded silty sandstone 30.5 to 32.0'; sandy siltstone 32.0 to 32.8'; hard, cemented, cross-bedded siltstone 32.8 to 33.6'; soft, silty sandstone 33.6 to 46.0'; weakly cemented sandstone 46.0 to 46.6'; soft, silty sandstone 46.6 to 52.5'; carbonaceous zones 43.2 to 44.8 & 50.0 to 50.5'; friable except from 32.8 to 33.6'; core lengths up to 18".

52.5-60.5 SILTY SHALE: Tan to light gray; oxidized; moist; firm; can be trimmed by knife; moderately plastic; thin-bedded with areas where bedding is not discernible; 3 to 18" core lengths.

60.5-62.4 SILTSTONE: Light gray; hard; cemented with calcium carbonate; can be scratched with knife; 1' core lengths.

62.4-66.3 SANDY SILTSTONE: Light gray to tan; oxidized; moist; can be trimmed by knife; trace of clay; 2 to 8" core lengths.

66.3-67.5 SANDSTONE: Light gray; moist; cross-bedded; fine grain; hard; cemented; can scratch with knife; 3 to 12" core lengths.

67.5-69.2 SILTY SHALE: Light gray; moist; bedding not discernible; low to medium plasticity; can be trimmed by knife; 2 to 6" core lengths.

69.2-88.8 SANDY SILTSTONE TO SILTY SANDSTONE: Light gray; moist; varies from sandy siltstone to silty sandstone; silty shale interbedded with silty sandstone & sandy siltstone 75.6 to 88.8'; cemented siltstone 81.6 to 82.2'; can be trimmed by knife & crushed between fingers; core lengths up to 18".

EXPLANATION

▯ CORE LOSS
▮ CORE RECOVERY

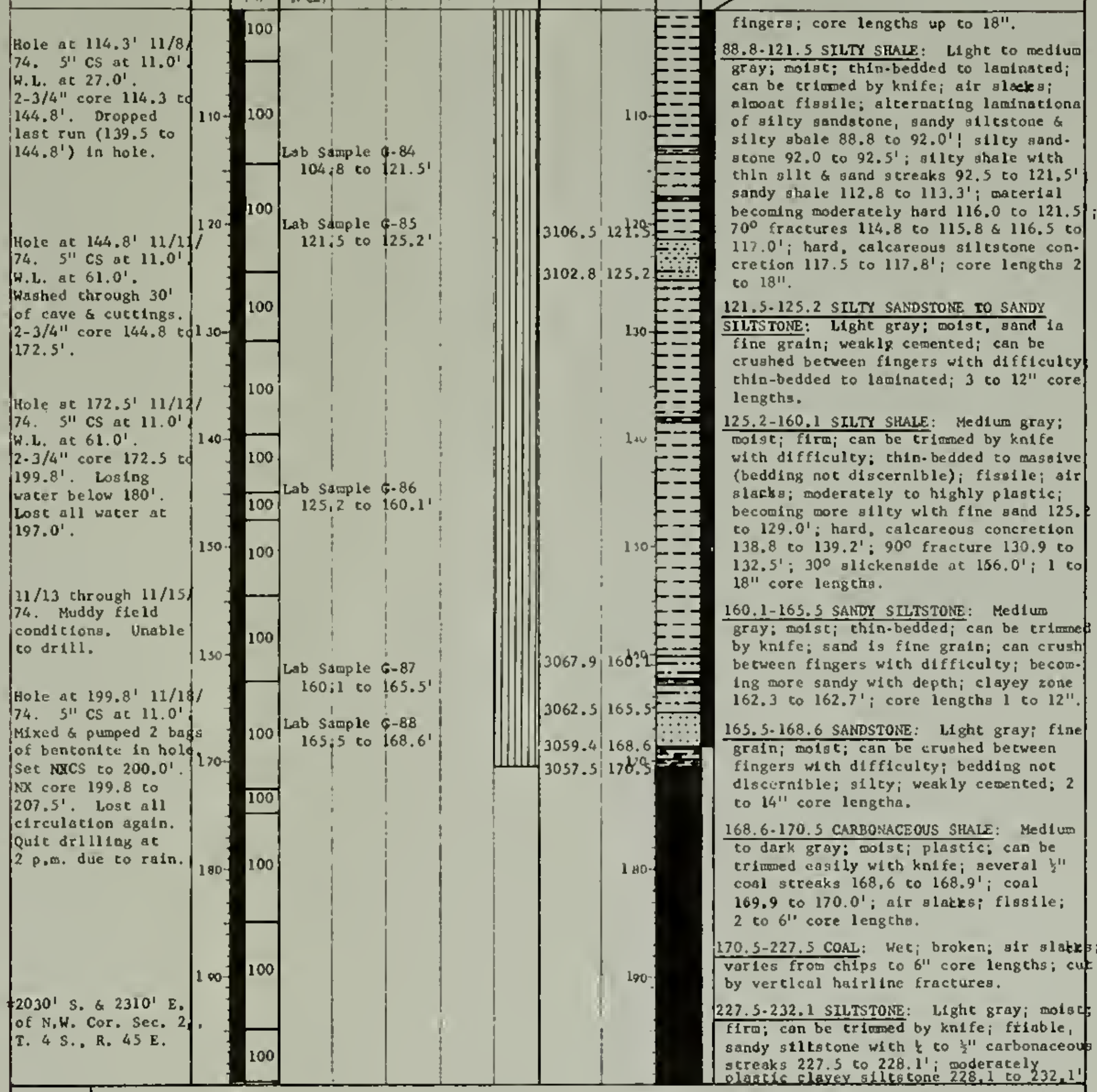
Type of hole . . . . . D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed . . . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Otter Creek Study Site PROJECT STATE Montana SHEET 1 OF 3 HOLE NO DH74-106

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 3

FEATURE Otter Creek Study Site PROJECT STATE Montana
DH HOLE NO 74-106 LOCATION * COORDS N. E. Altimeter GROUND ELEV 3228 DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 11/6/74 FINISHED 12/2/74 DEPTH OF OVERBURDEN 9.0 TOTAL DEPTH 247.6 BEARING --
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 158.1' 1/22/75 LOGGED BY Taucher LOG REVIEWED BY



Hole at 114.3' 11/8/74. 5" CS at 11.0'. W.L. at 27.0'. 2-3/4" core 114.3 to 144.8'. Dropped last run (139.5 to 144.8') in hole.

Hole at 144.8' 11/11/74. 5" CS at 11.0'. W.L. at 61.0'. Washed through 30' of cave & cuttings. 2-3/4" core 144.8 to 172.5'.

Hole at 172.5' 11/12/74. 5" CS at 11.0'. W.L. at 61.0'. 2-3/4" core 172.5 to 199.8'. Losing water below 180'. Lost all water at 197.0'.

11/13 through 11/15/74. Muddy field conditions. Unable to drill.

Hole at 199.8' 11/18/74. 5" CS at 11.0'. Mixed & pumped 2 bags of bentonite in hole. Set NXCS to 200.0'. NX core 199.8 to 207.5'. Lost all circulation again. Quit drilling at 2 p.m. due to rain.

*2030' S. & 2310' E. of N.W. Cor. Sec. 2, T. 4 S., R. 45 E.

Lab Sample G-84 104.8 to 121.5'
Lab Sample G-85 121.5 to 125.2'
Lab Sample G-86 125.2 to 160.1'
Lab Sample G-87 160.1 to 165.5'
Lab Sample G-88 165.5 to 168.6'

ELEVATION (FEET)	DEPTH (FEET)
3106.5	121.5
3102.8	125.2
3067.9	160.1
3062.5	165.5
3059.4	168.6
3057.5	170.5

88.8-121.5 SILTY SHALE: Light to medium gray; moist; thin-bedded to laminated; can be trimmed by knife; air slacks; almost fissile; alternating laminations of silty sandstone, sandy siltstone & silty shale 88.8 to 92.0'; silty sandstone 92.0 to 92.5'; silty shale with thin silt & sand streaks 92.5 to 121.5'; sandy shale 112.8 to 113.3'; material becoming moderately hard 116.0 to 121.5'; 70° fractures 114.8 to 115.8 & 116.5 to 117.0'; hard, calcareous siltstone concretion 117.5 to 117.8'; core lengths 2 to 18".

121.5-125.2 SILTY SANDSTONE TO SANDY SILTSTONE: Light gray; moist, sand is fine grain; weakly cemented; can be crushed between fingers with difficulty; thin-bedded to laminated; 3 to 12" core lengths.

125.2-160.1 SILTY SHALE: Medium gray; moist; firm; can be trimmed by knife with difficulty; thin-bedded to massive (bedding not discernible); fissile; air slacks; moderately to highly plastic; becoming more silty with fine sand 125.2 to 129.0'; hard, calcareous concretion 138.8 to 139.2'; 90° fracture 130.9 to 132.5'; 30° slickenside at 156.0'; 1 to 18" core lengths.

160.1-165.5 SANDY SILTSTONE: Medium gray; moist; thin-bedded; can be trimmed by knife; sand is fine grain; can crush between fingers with difficulty; becoming more sandy with depth; clayey zone 162.3 to 162.7'; core lengths 1 to 12".

165.5-168.6 SANDSTONE: Light gray; fine grain; moist; can be crushed between fingers with difficulty; bedding not discernible; silty; weakly cemented; 2 to 14" core lengths.

168.6-170.5 CARBONACEOUS SHALE: Medium to dark gray; moist; plastic; can be trimmed easily with knife; several ½" coal streaks 168.6 to 168.9'; coal 169.9 to 170.0'; air slacks; fissile; 2 to 6" core lengths.

170.5-227.5 COAL: Wet; broken; air slacks; varies from chips to 6" core lengths; cut by vertical hairline fractures.

227.5-232.1 SILTSTONE: Light gray; moist; firm; can be trimmed by knife; friable, sandy siltstone with ¼ to ½" carbonaceous streaks 227.5 to 228.1'; moderately plastic clayey siltstone 228.1 to 232.1' (approaching silty shale in zones); material below 228.1' is moderately hard; 2 to 8" core lengths.

EXPLANATION

▯ CORE LOSS
▮ CORE RECOVERY

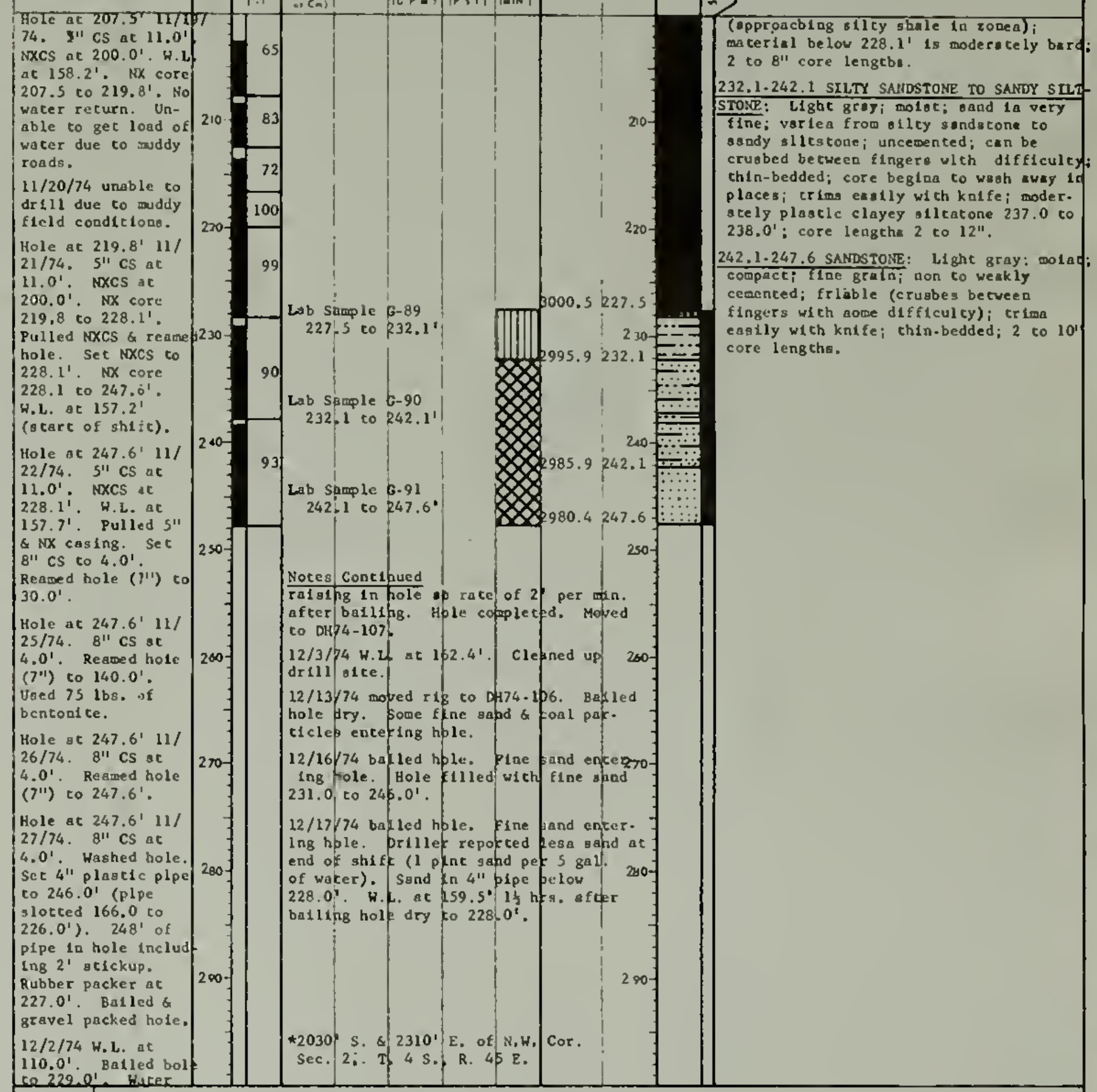
Type of hole . . . . . D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed . . . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Otter Creek Study Site PROJECT STATE Montana SHEET 2 OF 3 HOLE NO DH74-106

GEOLOGIC LOG OF DRILL HOLE

SHEET 3 OF 3

FEATURE Otter Creek Study Site PROJECT STATE Montana
DH HOLE NO 74-106 LOCATION * COORDS N. E. Altimeter GROUND ELEV 3228 DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 11/6/74 FINISHED 12/2/74 DEPTH OF OVERBURDEN 9.0 TOTAL DEPTH 247.6 BEARING --
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 158.1' 1/22/75 LOGGED BY Taucher LOG REVIEWED BY



Hole at 207.5' 11/19/74. 5" CS at 11.0'. NXCS at 200.0'. W.L. at 158.2'. NX core 207.5 to 219.8'. No water return. Unable to get load of water due to muddy roads.

11/20/74 unable to drill due to muddy field conditions.

Hole at 219.8' 11/21/74. 5" CS at 11.0'. NXCS at 200.0'. NX core 219.8 to 228.1'. Pulled NXCS & reamed hole. Set NXCS to 228.1'. NX core 228.1 to 247.6'. W.L. at 157.2' (start of shift).

Hole at 247.6' 11/22/74. 5" CS at 11.0'. NXCS at 228.1'. W.L. at 157.7'. Pulled 5" & NX casing. Set 8" CS to 4.0'. Reamed hole (7") to 30.0'.

Hole at 247.6' 11/25/74. 8" CS at 4.0'. Reamed hole (7") to 140.0'. Used 75 lbs. of bentonite.

Hole at 247.6' 11/26/74. 8" CS at 4.0'. Reamed hole (7") to 247.6'.

Hole at 247.6' 11/27/74. 8" CS at 4.0'. Washed hole. Set 4" plastic pipe to 246.0' (pipe slotted 166.0 to 226.0'). 248' of pipe in hole including 2' stickup. Rubber packer at 227.0'. Bailed & gravel packed hole.

12/2/74 W.L. at 110.0'. Bailed hole to 229.0'. Water

Notes Continued

raising in hole at rate of 2' per min. after bailing. Hole completed. Moved to DH74-107.

12/3/74 W.L. at 162.4'. Cleaned up drill site.

12/13/74 moved rig to DH74-106. Bailed hole dry. Some fine sand & coal particles entering hole.

12/16/74 bailed hole. Fine sand entering hole. Hole filled with fine sand 231.0 to 246.0'.

12/17/74 bailed hole. Fine sand entering hole. Driller reported less sand at end of shift (1 pint sand per 5 gal. of water). Sand in 4" pipe below 228.0'. W.L. at 159.5' 1½ hrs. after bailing hole dry to 228.0'.

*2030' S. & 2310' E. of N.W. Cor. Sec. 2, T. 4 S., R. 45 E.

Lab Sample G-89 227.5 to 232.1'
Lab Sample G-90 232.1 to 242.1'
Lab Sample G-91 242.1 to 247.6'

ELEVATION (FEET)	DEPTH (FEET)
3000.5	227.5
2995.9	232.1
2985.9	242.1
2980.4	247.6

232.1-242.1 SILTY SANDSTONE TO SANDY SILTSTONE: Light gray; moist; sand is very fine; varies from silty sandstone to sandy siltstone; uncemented; can be crushed between fingers with difficulty; thin-bedded; core begins to wash away in places; trims easily with knife; moderately plastic clayey siltstone 237.0 to 238.0'; core lengths 2 to 12".

242.1-247.6 SANDSTONE: Light gray; moist; compact; fine grain; non to weakly cemented; friable (crushes between fingers with some difficulty); trims easily with knife; thin-bedded; 2 to 10" core lengths.

EXPLANATION

▯ CORE LOSS
▮ CORE RECOVERY

Type of hole . . . . . D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed . . . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Otter Creek Study Site PROJECT STATE Montana SHEET 3 OF 3 HOLE NO DH74-106

Legend on Plate 9

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

OTTER CREEK STUDY SITE
OTTER CREEK COAL FIELD

GEOLOGIC LOG OF DH 74-106

DRAWN G.J. TAUCHER SUBMITTED
TRACED RECOMMENDED H.K. Dothe
CHECKED APPROVED
BILLINGS, MONTANA MARCH 1975
SHEETS 1 THROUGH 3 OF 3
1305-600-14

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 2

FEATURE Otter Creek Study Site PROJECT STATE Montana
DH HOLE NO. 74-107 LOCATION * COORDS. N. E. Altimeter GROUND ELEV 3105. DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 12/3/74 FINISHED 12/12/74 DEPTH OF OVERBURDEN 3.0 TOTAL DEPTH 146.1 BEARING --
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 45.4' 1/22/75 LOGGED BY Taucher LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS:

Hole started 12/3/74. Drive sample 0 to 15'. 5" CS set to 15'.

Hole at 15.0' 12/4/74. 5" CS at 15.0'. 2-3/4" wireline core 15.0 to 39.9'. Lost water at 15.0'. Set 5" CS to 26.6'. 100% water return below 28.6'.

Hole at 39.9' 12/5/74. 5" CS at 28.6'. W.L. at 32.2'. 2-3/4" wireline core 39.9 to 102.3'. No water loss.

*1400' N. & 900' W. of S.E. Cor. Sec. 2, T. 4 S., R. 45 E.

CORE RECOVERY (%): 100, 100, 100, 100, 37, 100, 100, 100, 100, 100, 100, 100, 100, 100, 100

PERCOLATION TESTS:

Lab Sample G-92 1.0 to 3.0'

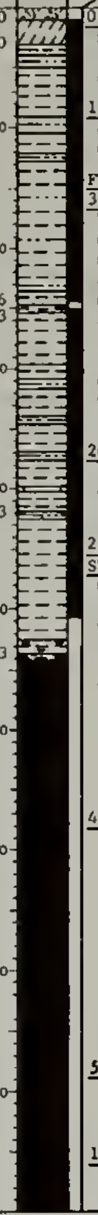
Lab Sample G-93 3.0 to 15.0'

Lab Sample G-94 15.0 to 24.6'

Lab Sample G-95 25.3 to 42.3'

Lab Sample G-96 42.3 to 50.8'

ELEVATION (FEET)	DEPTH (FEET)
3104.0	1.0
3102.0	3.0
3080.4	24.6
3079.7	25.3
3062.7	42.3
3050.7	54.3



CLASSIFICATION AND PHYSICAL CONDITION:

0-1.0 CLAYEY SAND: Medium gray; moist; roots; slightly organic; approx. 40% low plasticity fines; approx. 60% fine sand (SC).

1.0-3.0 SANDY CLAY: Tan; oxidized; damp; approx. 60% medium plasticity fines; approx. 40% fine sand (CL).

FT. UNION FORMATION - TERTIARY

3.0-24.6 SILTY SHALE TO CLAYEY SILTSTONE: Tan to brown; oxidized; damp becoming moist with depth; varies from silty shale to clayey siltstone; low to moderate plasticity; trims easily with knife; moderately soft; thin-bedded; sandy siltstone 4.0 to 5.0, 9.0 to 10.5, 12.0 to 12.5 & 15.0 (?) to 17.0 (?); plastic silty shale 23.6 (?) to 24.6'; highly oxidized, 90° joint 11.0 to 12.5' (lost water); 90° oxidized joint 24.0 to 24.6'; core lengths up to 8".

24.6-25.3 CARBONACEOUS SHALE: Dark gray to almost black; moist; soft; cuts easily with knife; very plastic; core lengths 1 to 2".

25.3-42.3 SILTY SHALE WITH SANDY SILTSTONE: Tan to grey-brown; oxidized; moist; moderately hard but can be trimmed by knife; thin-bedded to zones where bedding is not distinct; silty shale 25.3 to 29.6'; silty shale with 1 to 8" zones of sandy siltstone at various intervals 29.6 to 41.8'; moderately plastic; hard, calcium carbonate cemented concretions (scratches with knife) 39.7 to 40.3 & 41.8 to 42.3'; 80° oxidized joint at 27.4'; core lengths 1 to 14".

42.3-54.3 SHALE: Medium gray 42.3 to 52.3'; dark gray to black & carbonaceous 52.3 to 54.3'; moist; plastic; trims easily with knife; begins to air slack; bedding not readily discernible; could be bentonitic; ½" coal at 53.6'; alternating zones of black coal & dark gray to black shale 53.9 to 54.3'; 20° slickenside at 49.8 & 45° slickensides at 50.2 & 50.3'; several 15 to 40° slickensides 53.9 to 54.3'; core lengths 2 to 24".

54.3-120.3 COAL: Moist to wet; cut by vertical, hairline fractures; broken in 1 to 8" core lengths; several 15 to 40° slickensides 54.3 to 55.0'.

120.3-127.0 SILTY SHALE: Light gray; moist; firm; can be trimmed by knife with difficulty; thin-bedded; plastic

EXPLANATION

☐ CORE LOSS
■ CORE RECOVERY

Type of hole ... D = Diamond, N = Noystellite, S = Shot, C = Churn
Hole sealed ... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Otter Creek Study Site PROJECT STATE Montana SHEET 1 OF 2 HOLE NO. DH74-107

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 2

FEATURE Otter Creek Study Site PROJECT STATE Montana
DH HOLE NO. 74-107 LOCATION * COORDS. N. E. Altimeter GROUND ELEV 3105. DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 12/3/74 FINISHED 12/12/74 DEPTH OF OVERBURDEN 3.0 TOTAL DEPTH 146.1 BEARING --
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 45.4' 1/22/75 LOGGED BY Taucher LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS:

Hole at 102.3' 12/6/74. 5" CS at 28.6'. 2-3/4" core 102.3 to 127.3'. Losing some drill water.

Hole at 127.3' 12/10/74. 5" CS at 28.6'. W.L. at 45.5'. 2-3/4" wireline core 127.3 to 146.1'. Used bentonite while drilling. Pulled 5" CS. Set 8" CS to 3.0'. Driller reported hole full of cuttings below 45'.

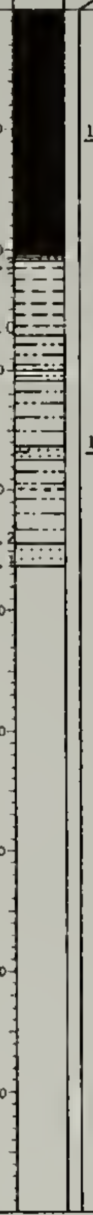
Hole at 146.1' 12/11/74. 8" CS at 3.0'. Hole full of drill mud. Reamed (7½") hole 0 to 95.0'.

Hole at 146.1' 12/12/74. Reamed hole 95.0 to 141.5'. Set 143.5' of 4" pipe in hole (2' stickup). Pipe slotted 61.5 to 121.5'. Packer rubber at 122.5'. 1000 gallons of water pumped into 4" pipe to wash out hole. Gravel (pea) packed hole. Bailed hole. Hole completed. Pulled 3' of 8" CS 12/16/74. W.L. at 44.0'.

*1400' N. & 900' W. of S.E. Cor. Sec. 2, T. 4 S., R. 45 E.

CORE RECOVERY (%): 100, 100, 100, 100, 100, 100, 100, 100

ELEVATION (FEET)	DEPTH (FEET)
2984.7	120.3
2978.0	127.0
2960.8	144.2
2958.9	146.1



CLASSIFICATION AND PHYSICAL CONDITION:

when worked; sandy siltstone 120.3 to 120.6'; coal 120.6 to 120.7'; silty shale 120.7 to 127.0' with sandy zones 123.0 to 124.0'; begins to air slack; 2 to 18" core lengths.

127.0-144.2 SANDY SILTSTONE: Light gray; moist; thin-bedded with zones where bedding is not discernible; firm (difficult trimming with knife) 127.0 to 132.7, 134.5 to 137.0 & 140.0 to 144.2'; soft to moderately soft (cuts easily with knife) 132.7 to 134.5 & 137.0 to 140.0'; sandy siltstone 127.0 to 129.8'; clayey to sandy siltstone 129.8 to 130.9'; sandy siltstone 130.9 to 136.1'; silty sandstone 136.1 to 137.2'; sandy siltstone 137.2 to 144.2'; more sandy with depth 137.2 to 144.2'; carbonaceous streaks 139.7 to 139.9'; core lengths ½ to 24".

144.2-146.1 SANDSTONE: Light grey; moist; thin-bedded; moderately hard but can be crushed between fingers; weakly cemented; fine grain; begins to wash away during drilling; some silt; ½ to 8" core lengths.

EXPLANATION

☐ CORE LOSS
■ CORE RECOVERY

Type of hole ... D = Diamond, N = Noystellite, S = Shot, C = Churn
Hole sealed ... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Otter Creek Study Site PROJECT STATE Montana SHEET 2 OF 2 HOLE NO. DH74-107

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 1

FEATURE Otter Creek Study Site PROJECT STATE Montana
DH HOLE NO. 75-108 LOCATION * COORDS. N. E. Altimeter GROUND ELEV 329.3 DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 1/30/75 FINISHED 2/7/75 DEPTH OF OVERBURDEN 10.7 TOTAL DEPTH 321.3 BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 193.4' 3/18/75 LOGGED BY Driller (Davis) LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS:

Hole started 1/30/75. 7½" drag bit 0 to 51.3'. 8" CS set to 3.0'.

Hole at 51.3' 1/31/75. 8" CS at 3.0'. Mud at 20'. 7½" drag bit 51.3 to 111.3'.

Hole at 111.3' 2/3/75. 8" CS at 3.0'. Mud at 20'. 7½" drag bit 111.3 to 191.3'.

Hole at 191.3' 2/4/75. 8" CS at 3.0'. Mud at 30'. 7½" drag bit 191.3 to 231.3'. 5-5/8" rock bit 231.3 to 241.3'.

Hole at 241.3' 2/5/75. 8" CS at 3.0' W.L. at 49.0'. Reamed hole with 7½" drag bit 231.3 to 241.3'. Drag bit 241.3 to 298.0'

Hole at 298.0' 2/6/75. 8" CS at 3.0' W.L. at 60.0'. 7½" drag bit 298.0 to 321.3'. Washed hole. Installed 322.8' of 4" plastic pipe (1.5' stickup). Pipe perforated 257.0 to 317.0'. Gravel (pea) packed around pipe.

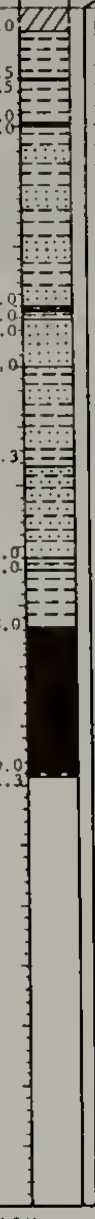
Hole at 321.3' 2/7/75. 8" CS at 3.0' W.L. at 119.5'. Pulled 8" CS. Bailed hole to 205.0'. (Bailed water fairly clean). Moved drill rig.

*2600' N. & 800' W. of S.E. Cor. Sec. 35, T. 3 S., R. 45 E.

CORE RECOVERY: No core recovery

PERCOLATION TESTS: Hole logged from cuttings. No samples taken.

ELEVATION (FEET)	DEPTH (FEET)
3283.0	10.0
3263.5	29.5
3262.5	30.5
3245.0	48.0
3243.0	50.0
3168.0	125.0
3166.0	127.0
3163.0	130.0
3143.0	150.0
3101.7	191.3
3063.0	230.0
3058.0	235.0
3035.0	258.0
2974.0	319.0
2971.7	321.3



CLASSIFICATION AND PHYSICAL CONDITION:

0-10.0 SILT:

FT. UNION FORMATION - TERTIARY

10-29.5 SHALE:

29.5-30.5 COAL:

30.5-48.0 SHALE:

48.0-50.0 COAL:

50.0-125.0 SHALE & SILTSTONE:

125.0-127.0 CARBONACEOUS SHALE & COAL:

127.0-130.0 SHALE WITH SANDSTONE SEAMS:

130.0-150.0 SANDSTONE:

150.0-191.3 SHALE WITH SANDSTONE SEAMS:

191.3-230.0 SANDY SHALE:

230.0-235.0 CONCRETION: Hard, Shaley

235.0-258.0 SHALE:

258.0-319.0 COAL:

319.0-321.3 SHALE:

EXPLANATION

☐ CORE LOSS
■ CORE RECOVERY

Type of hole ... D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed ... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Otter Creek Study Site PROJECT STATE Montana SHEET 1 OF 1 HOLE NO. DH 75-108

Legend on Plate 9

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

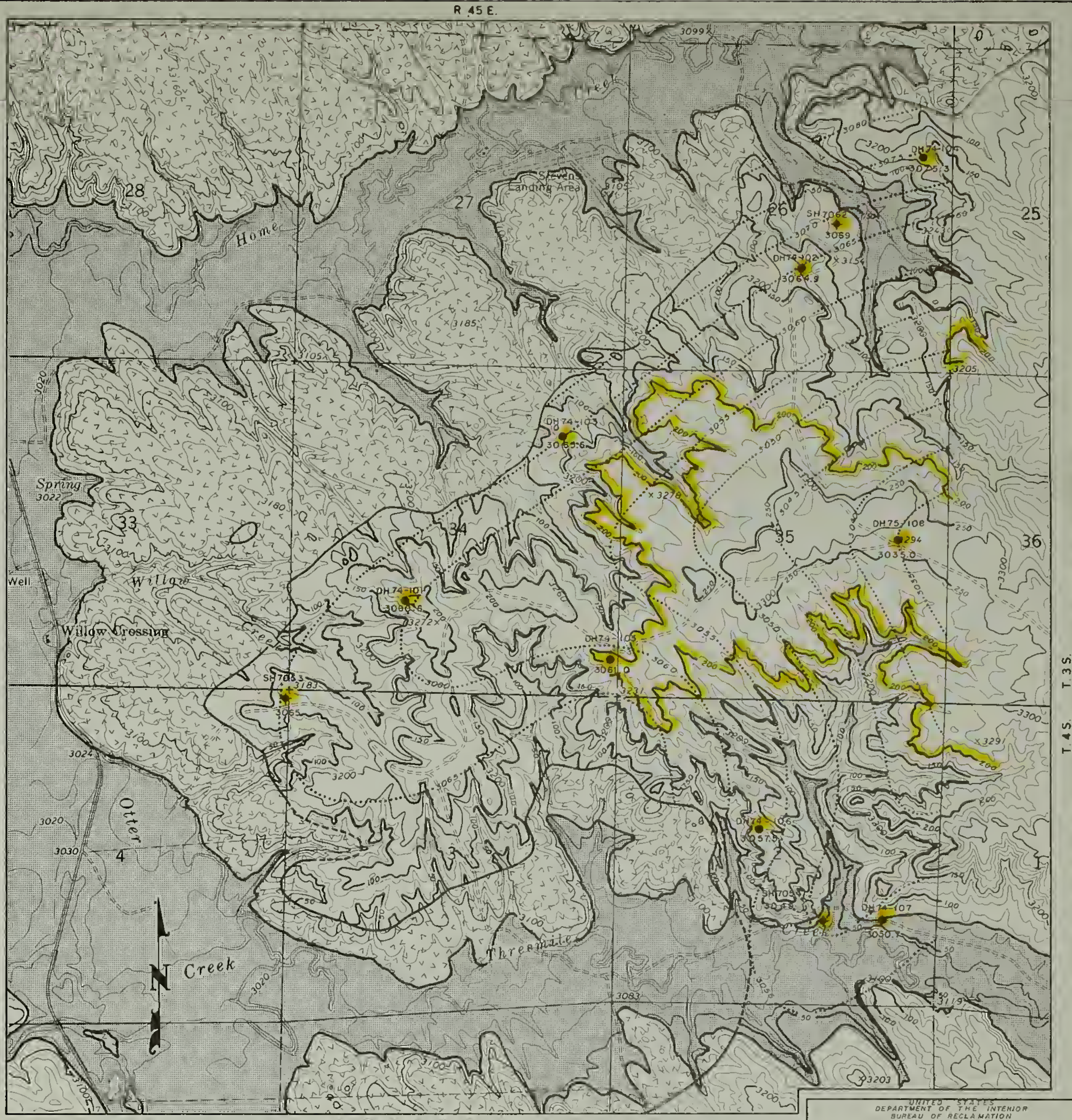
OTTER CREEK STUDY SITE
OTTER CREEK COAL FIELD

GEOLOGIC LOG OF DH 74-107
AND
GEOLOGIC LOG OF DH 74-108

DRAWN G.J. TAUCHER SUBMITTED
TRACED RECOMMENDED H.R. DeRees
CHECKED APPROVED

BILLINGS, MONTANA MARCH 1975
SHEETS 1 THROUGH 2 OF 2 (107) AND SHEET 1 OF 1 (108)
1305-600-15

PLATE 18



L E G E N D

RECENT	▨	ALLUVIUM-SAND, SILT & CLAY. UP TO 50 FT THICK.
PALEOCENE	☐	FT. UNION FM. (TONGUE RIVER MEMBER) SANDSTONE, SILTSTONE & SHALE. CONTAINS COAL BEDS UP TO 65-FT IN THICKNESS
	∨ < ∨	CLINKER-BAKED SANDSTONE, SILTSTONE & SHALE OF THE FT UNION FM PRODUCED BY BURNING OF THE KNOBLOCK COAL BED. UP TO 200-FT THICK

1000 0 1000 2000
SCALE OF FEET

—·—	GEOLOGIC CONTACT-DASHED WHERE INFERRED.
—100—	CONTOUR SHOWING THICKNESS OF OVERBURDEN ABOVE KNOBLOCK COAL BED.
DH74-101 ● 3060.6	USBR DRILL HOLE (ELEVATION ON TOP OF KNOBLOCK COAL BED.)
SH7062 ◆ 3069	MONTANA BUREAU OF MINES & GEOLOGY DRILL HOLE (ELEVATION ON TOP OF KNOBLOCK COAL BED) TAKEN FROM MBMG BUL. 91.
··3050··	STRUCTURE CONTOUR ON TOP OF KNOBLOCK COAL BED

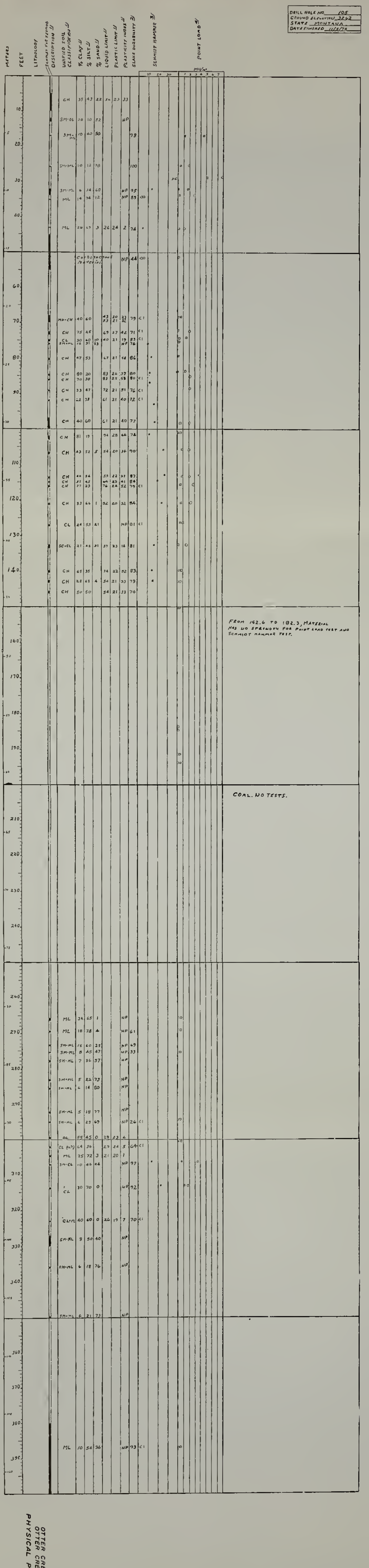
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

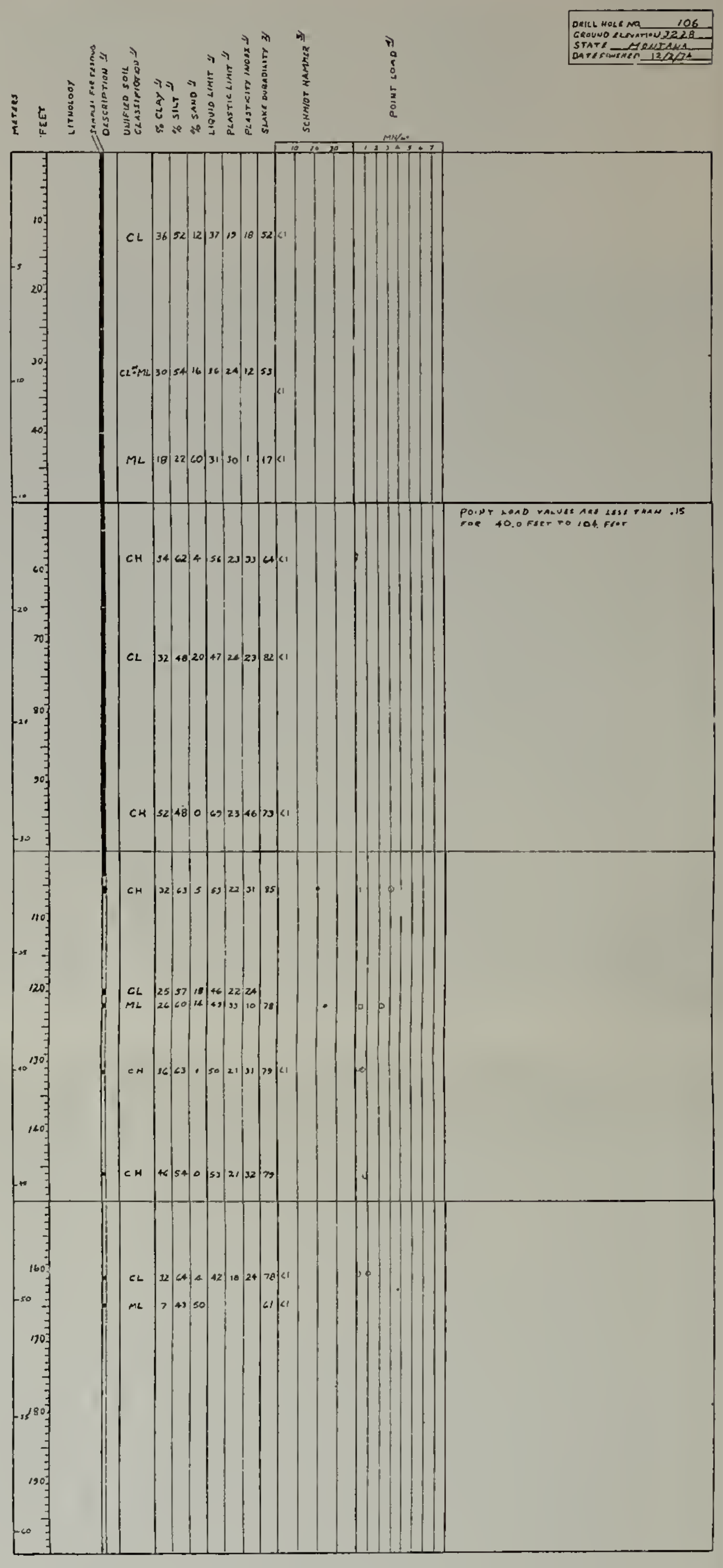
OTTER CREEK STUDY SITE
OTTER CREEK COAL FIELD

OVERBURDEN THICKNESS MAP

GEOLOGY G J TAUCHER SUBMITTED
DRAWN G J TAUCHER RECOMMENDED
CHECKED APPROVED

BILLINGS, MONTANA FEBRUARY 1975 1305-600-16





EXPLANATORY NOTES

1/ Classification and gradation tests were performed following procedures listed in the 2nd Edition of the Earth Manual, a water resources technical publication by the Bureau of Reclamation, U. S. Department of the Interior, which follows the appropriate ASTM Designation for classification and testing of earth materials.

2/ The slake durability is a measurement of resistance of rock to weakening and/or disintegration resulting from cyclic wetting and drying. The values shown are the percent of material remaining after the test.

3/ The Schmidt Rebound Hammer is essentially a non-destructive, portable test device which expends a definite amount of stored energy (0.54 foot-pounds) impelling a steel hammer of uniform cross-sectional area against the materials surface. The amount of rebound of the hammer after striking the surface is indicated on a graduated scale. This number is designated as "R" and has been correlated with compressive strength of concrete and rock. Values shown are in "R"'s.

4/ The point load test measures the uniaxial strength of a rock sample in the form of specimens of regular geometry. The test is mainly intended for strength classification and characterization of intact rock. Values shown by squares are the compressive strengths parallel to bedding and by circles normal to the bedding.

OTTER CREEK STUDY SITE
OTTER CREEK COAL FIELD
PHYSICAL PROPERTIES DATA

COAL RESOURCES

General

This report is part of a program of study for the Bureau of Land Management aimed at determining the feasibility of surface mining and surface restoration of coal-bearing areas in the western United States. Much of the report is offered as background needed in understanding the relatively short pertinent parts of the Energy Mineral Rehabilitation Inventory and Analysis study.

The bases for this report are core drilling, logging, sampling for coal and rock analyses, and geologic mapping by the Bureau of Reclamation and the U.S. Geological Survey in conjunction with analytical data provided by the Bureau of Mines and Geological Survey laboratories.

Coalbeds on the Otter Creek EMRIA study site are in the Tongue River Member of the Fort Union Formation of Paleocene age and include thin beds above the Knoblock bed, which is about 60 feet thick, and the Flowers-Goodale bed, about 10 feet thick, 120 feet below the Knoblock. Bureau of Mines analyses show the thicker beds to be subbituminous C in rank; 24 samples of the Knoblock have an average of 8,110 Btu as received.

The average ash content of Knoblock coal in five drill holes is 5.5 percent and that of Flowers-Goodale in three drill holes is 8.2 percent. Average sulfur content in the Knoblock is 0.15 percent; in the Flowers-Goodale 0.46 percent.

Estimated coal resources in the Knoblock coal on the EMRIA site is 126 million tons underlying 200 feet or less of overburden. The ratio of cubic yards of overburden to total estimated coal resources is about 2 cubic yards of overburden per ton of coal.

Analyses of coal, coal-ash, and rock samples are on average similar to those for other coals of the Northern Great Plains and average rock analyses for the earths crust. Only the selenium content of Knoblock coal is more than an order of magnitude higher than that in the continental crust.

Origin

Coal has been defined as "a readily combustible rock containing more than 50 percent by weight and more than 70 percent by volume of carbonaceous material, formed from compaction or induration of variously altered plant remains similar to those of peaty deposits. Differences in the kinds of plant materials (type), in degree of metamorphism (rank), and range of impurity (grade), are characteristics of the varieties of coal" (Schopf, 1956). Inherent in the definition is the specification that the coal originated as a mixture of organic plant remains and inorganic mineral matter that accumulated in a manner similar to that in which modern-day peat deposits are formed.

The peat then underwent a long, extremely complex process called "coalification" during which diverse physical and chemical changes occurred as the peat changed to coal, and the coal assumed the characteristics by which are differentiated members of the series from each other. The factors that affect the composition of coals have been summarized by Francis (1961, p. 2) as follows:

1) The mode of accumulation and burial of the plant debris forming the deposits.

2) The age of the deposits and their geographical distribution.

3) The structure of the coal-forming plants, particularly details of structure that affect chemical composition or resistance to decay.

4) The chemical composition of the coal-forming debris and its resistance to decay.

5) The nature and intensity of the plant-decaying agencies.

6) The subsequent geological history of the residual products of decay of the plant debris forming the deposits.

For extended discussions of these factors, the reader is referred to such standard works as Moore (1940), Lowry (1945), Tomkeieff (1954), Francis (1961), and Lowry (1963).

Classification

Coals can be classified in many ways (Tomkeieff, 1954, p. 9; Moore, 1940, p. 113; Francis, 1961, p. 361), but the classification by rank--that is, by degree of metamorphism in the progressive series which begins with peat and ends with graphocite (Schopf, 1966)-- is the most commonly used system. Classification by type of plant materials is commonly used as a descriptive adjunct to rank classification when sufficient megascopic and microscopic information is available, and classification by type and quantity of impurities (grade) is frequently used when utilization of the coal is being considered. Other categorizations are possible and are commonly employed in discussion of coal resources--such factors as the weight (specific gravity) of the coal, the thickness and areal extent of the individual coalbeds, and the thickness of overburden are generally considered.

Rank of Coal

The designation of a coal within the metamorphic series, which begins with peat and ends with graphocite, is dependent upon the temperatures and pressure to which the coal has been subjected and the duration of time of subjection. Because coal is largely derived from plant material, coal is mostly composed of carbon, hydrogen, and oxygen, along with smaller quantities of nitrogen, sulfur, and other elements. The increase in rank of coal as it undergoes progressive metamorphism is indicated by changes in the proportions of the major coal constituents--the higher rank coals have more carbon and less hydrogen and oxygen than the lower ranks.

Two standardized forms of coal analyses--the proximate analysis and the ultimate analysis--are generally made; though sometimes only the less complicated and less expensive proximate analysis is made. The analyses are described as follows (U.S. Bur. Mines, 1965, p. 121-122):

> "The proximate analysis of coal involves the determination of four constituents: (1) water, called moisture; (2) mineral impurity, called ash, left when the coal is completely burned; (3) volatile matter, consisting of gases or vapors driven out when coal is heated to certain temperatures; and (4) fixed carbon, the solid or cakelike residue that burns at higher temperatures after volatile matter has been driven off. Ultimate analysis involves the determination of carbon and hydrogen as found in the gaseous products of combustion, the determination of sulfur, nitrogen, and ash in the material as a whole, and the estimation of oxygen by difference."

Most coals are burned to produce heat energy so the heating value of the coal is an important property. The heating value (Calorific value) is commonly expressed in British thermal units (Btu) per pound: 1 Btu is the amount of heat required to raise the temperature of 1 lb. of water 1°F (in the metric system, heating value is expressed in kilogram-calories per kilogram). Additional tests are sometimes made, particularly to determine the caking, coking, and other properties, such as tar yield, which affect classification or utilization.

Figure 3 compares in histogram form the heating value and the moisture, volatile matter, and fixed carbon contents of coals of different ranks.

Various schemes for classifying coals by rank have been proposed and used but the one most commonly employed in the United States is the "Standard specifications for classification of coals by rank," adopted by the American Society for Testing and Materials (1974) as shown in table 3.

The ASTM classification system differentiates coals into classes and groups on the basis of mineral-matter-free fixed carbon or volatile matter and the heating value supplemented by determination of agglomerating (caking) characteristics. "Coals which in the volatile matter determination produce either an agglomerate button that will support a 500-g weight without pulverizing, or a button showing swelling or cell structure, shall be considered agglomerating from the standpoint of classification (ASTM, 1974, p. 56)."

Location and sample intervals of drill holes are shown on plates 6 and 7.

Figure 3.

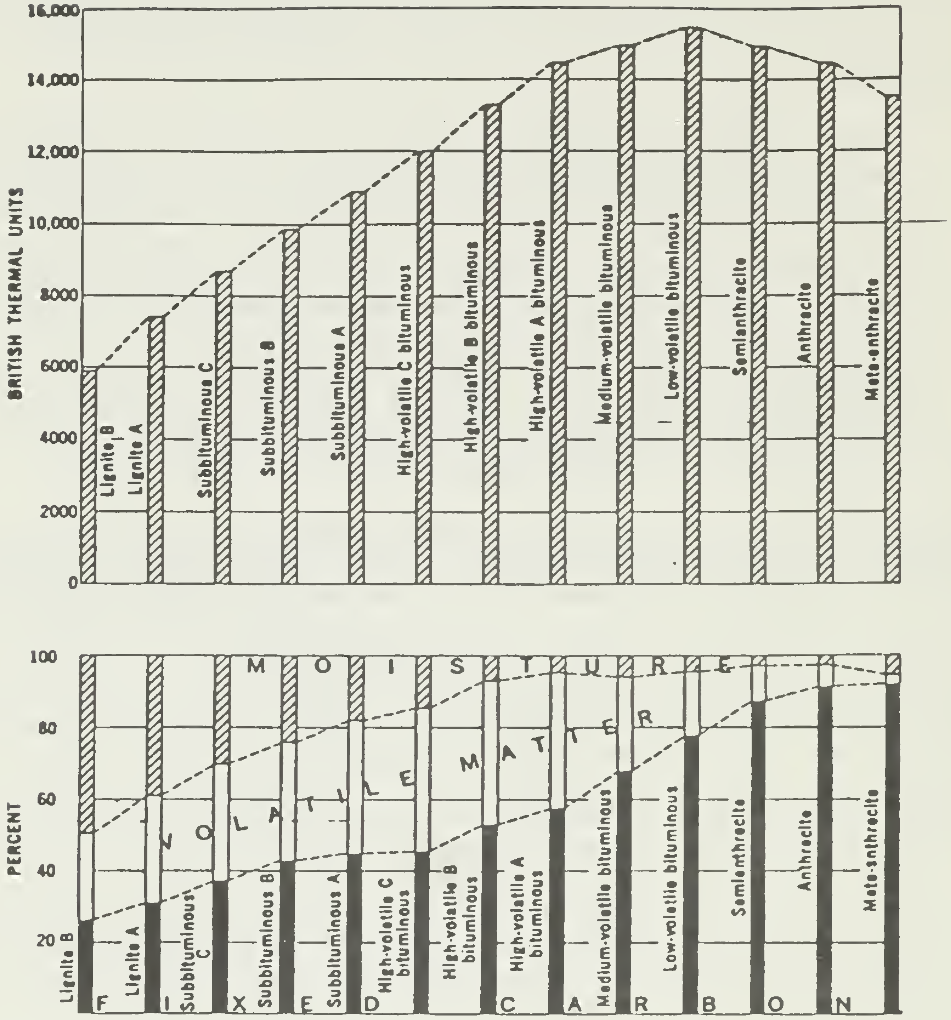


Figure 3.--Comparison on moist, mineral-matter-free basis of heat values and proximate analyses of coal of different ranks.

Table 3 Classification of coals by rank[1]
[American Society for Testing and Materials Standard D388-66 (Reapproved 1972)]

Class	Group	Fixed Carbon Limits, percent (Dry, Mineral-Matter-Free Basis)		Volatile Matter Limits, percent (Dry, Mineral, Matter-Free Basis)		Calorific Value Limits, Btu per pound (Moist,[2] Mineral-Matter-Free Basis)		Agglomerating Characte
		Equal or Greater Than	Less Than	Greater Than	Equal or Less Than	Equal or Greater Than	Less Than	
I. Anthracite	1. Meta-anthracite	98	...	...	2	...	...	nonagglomerating
	2. Anthracite	92	98	2	8	...	...	
	3. Semianthracite[3]	86	92	8	14	...	...	
II. Bituminous	1. Low volatile bituminous coal	78	86	14	22	...	...	Commonly agglomerating[5]
	2. Medium volatile bituminous coal	69	78	22	31	...	...	
	3. High volatile A bituminous coal	...	69	31	...	14 000[4]	...	
	4. High volatile B bituminous coal	...	...	...	...	13 000[4]	14 000	
	5. High volatile C bituminous coal	...	...	...	...	11 500	13 000	
						10 500	11 500	agglomerating
III. Subbituminous	1. Subbituminous A coal	...	...	...	...	10 500	11 500	nonagglomerating
	2. Subbituminous B coal	...	...	...	...	9 500	10 500	
	3. Subbituminous C coal	...	...	...	...	8 300	9 500	
IV. Lignitic	1. Lignite A	...	...	...	...	6 300	8 300	
	2. Lignite B	...	...	...	...	...	6 300	

[1] This classification does not include a few coals, principally nonbanded varieties, which have unusual physical and chemical properties and which come within the limits of fixed carbon or calorific value of the high-volatile bituminous and subbituminous ranks. All of these coals either contain less than 48 percent dry, mineral-matter-free fixed carbon or have more than 15,500 moist, mineral-matter-free British thermal units per pound.

[2] Moist refers to coal containing its natural inherent moisture but not including visible water on the surface of the coal.

[3] If agglomerating, classify in low-volatile group of the bituminous class.

[4] Coals having 69 percent or more fixed carbon on the dry, mineral-matter-free basis shall be classified according to fixed carbon, regardless of calorific value.

[5] It is recognized that there may be nonagglomerating varieties in these groups of the bituminous class, and there are notable exceptions in high volatile C bituminous group.

Table 3.

As pointed out by the ASTM (1974, p. 55), a standard rank determination cannot be made unless the samples were obtained in accordance with standardized sampling procedures (Snyder, 1950; Schopf, 1960). However, nonstandard samples may be used for comparative purposes through determinations designated as "apparent rank."

The proximate, ultimate, Btu, and forms of sulfur analyses of samples of the Otter Creek coals are presented in table 4. The analyses indicate that the Otter Creek coals are of subbituminous C rank.

The location of drill holes from which samples were taken is shown on plate 5, "Geologic and Investigations Map." Table 4 and other tables of analyses are keyed to lithologic logs shown on plates 6 and 7.

Twenty-four samples of the Knoblock coal have an average of 8,110 Btu as received. The average ash content of samples of the Knoblock coal as received from five drill holes is 5.5 percent and that of the Flowers-Goodale coal in three drill holes is 8.2 percent. Average sulfur content in the Knoblock coal is 0.15 percent and in the Flowers-Goodale coal 0.46 percent.

Type of Coal

Classification of coals by type--that is, according to the types of plant materials present--takes many forms, such as the "rational analysis" of Francis (1961), or the semicommercial "type" classification commonly used in the coalfields of the eastern United States (U.S. Bur. Mines, 1965, p. 123). However, most of the type classifications are based on the same, or similar, gross distinctions in plant material used by Tomkeieff (1954, table II, and p. 9), who divided the coals into three series: humic coals, humic-sapropelic coals, and sapropelic coals, based upon the nature of the original plant materials. The humic coals are largely composed of the remains of the woody parts of plants and the sapropelic coals are largely composed of the more resistant waxy, fatty, and resinous parts of plants, such as cell walls, spore-coatings, pollen, and resin particles, and coals composed of algae materials. Most coals fall into the humic series, with some coals being mixtures of humic and sapropelic elements and, therefore, falling into the humic-sapropelic series. The sapropelic series is quantitatively insignificant and when found is commonly regarded as an organic curiosity.

In common with most coals of the United States, the Otter Creek coals fall largely in the humic series.

Grade of Coal

Classification of coal by grade, or quality, is based largely on the content of ash, sulfur, and other constituents that adversely affect utilization. Most detailed coal resource evaluations of the past do not categorize known coal resources by grade but coals of the United States have been classified by sulfur content in a gross way (DeCarlo and others, 1966).

The range and average of the ash and sulfur contents of 642 coal samples from all parts of the United States were determined by Fieldner, Rice, and Moran (1942).

Ash and sulfur contents of United States coals

Number of samples	Ash, percent		Sulfur, percent	
	Range	Average	Range	Average
642	2.5 - 32.6	8.9	0.3 - 7.7	1.9

The coal in the Otter Creek area is slightly below average in ash content and is considerably below average in sulfur content. The average ash content as received of Knoblock coal in five drill holes is 5.5 percent and that of Flowers-Goodale coal in three drill holes is 8.2 percent. Average sulfur content in the Knoblock is 0.15 percent; in the Flowers-Goodale--0.46 percent.

Table 4--Proximate, ultimate, Btu and forms of sulfur analyses of samples of the Knoblock and Flowers-Goodale coal beds in Drill Hole 101, Tongue River Member of the Fort Union Formation (Paleocene age), Willow Crossing quadrangle, Powder River County, Montana. (All analyses except Btu are in percent. Original moisture content may be slightly more than shown because samples were collected and transported in plastic bags to avoid metal contamination. Form of analyses: A, as received; B, moisture free; C, moisture and ash free. All analyses by Coal Analysis Section, U.S. Bureau of Mines, Pittsburgh, Pa.)

SAMPLE NO.	FORM OF ANALYSIS	PROXIMATE ANALYSIS				ULTIMATE ANALYSIS					BTU VALUE	FORMS OF SULFUR		
		Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur		Sulfate	Pyritic	Organic
Knoblock bed, composite core bench sample, depth 198.4 to 215.2 ft														
D169041	A	30.9	27.0	34.7	7.4	6.6	45.4	0.8	39.7	0.1	7790	0.02	0.04	0.07
	B	--	39.0	50.3	10.7	4.6	65.7	1.1	17.7	.2	11270	.02	.06	.10
	C	--	43.7	56.3	--	5.1	73.6	1.3	19.8	.2	12620	.03	.07	.11
Knoblock bed, composite core bench sample, depth 215.2 to 230.0 ft														
D169042	A	30.3	28.7	35.4	5.6	6.7	47.7	0.7	39.2	0.1	8220	0.02	0.04	0.09
	B	--	41.2	50.8	8.0	4.8	68.5	1.0	17.5	.2	11790	.02	.06	.12
	C	--	44.8	55.2	--	5.2	74.5	1.1	19.0	.2	12820	.03	.07	.13
Knoblock bed, composite core bench sample, depth 230.0 to 245.0 ft														
D169043	A	28.2	29.3	36.0	6.5	6.5	48.6	0.7	37.6	0.1	8370	0.02	0.04	0.04
	B	--	40.8	50.1	9.1	4.7	67.6	1.0	17.5	.1	11660	.02	.06	.05
	C	--	44.9	55.1	--	5.2	74.4	1.1	19.2	.1	12830	.03	.07	.05
Knoblock bed, composite core bench sample, depth 245.0 to 259.4 ft														
D169044	A	29.3	26.8	36.5	7.4	6.4	46.9	0.7	38.4	0.2	8050	0.01	0.11	0.02
	B	--	37.9	51.6	10.5	4.4	66.3	1.1	17.5	.2	11390	.02	.18	.04
	C	--	42.4	57.6	--	4.9	74.1	1.2	19.5	.3	12720	.03	.21	.04
Flowers-Goodale bed, composite core bench sample, depth 375.7 to 385.4 ft														
D169481	A	26.4	28.7	39.1	5.8	6.2	51.2	0.9	35.5	0.4	8710	0.01	0.07	0.29
	B	--	39.0	53.1	7.9	4.4	69.5	1.2	16.5	.5	11830	.01	.09	.39
	C	--	42.4	57.6	--	4.8	75.4	1.3	18.0	.5	12840	.01	.10	.40

Table 4.--Proximate, ultimate, Btu and forms of sulfur analyses of samples of the Knoblock and Flowers-Goodale coal beds in Drill Hole 102, Tongue River Member of the Fort Union Formation (Paleocene age), Willow Crossing quadrangle, Powder River County, Montana. (All analyses except Btu are in percent. Original moisture content may be slightly more than shown because samples were collected and transported in plastic bags to avoid metal contamination. Form of analyses: A, as received; B, moisture free; C, moisture and ash free. All analyses by Coal Analysis Section, U.S. Bureau of Mines, Pittsburgh, Pa.)

SAMPLE NO.	FORM OF ANALYSIS	PROXIMATE ANALYSIS				ULTIMATE ANALYSIS					BTU VALUE	FORMS OF SULFUR		
		Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur		Sulfate	Pyritic	Organic
Knoblock bed, composite core bench sample, depth 127.7 to 136.4 ft														
D169477	A	29.1	29.8	35.6	5.5	6.6	48.6	0.7	38.4	0.2	8220	0.01	0.01	0.15
	B	--	42.0	50.2	7.8	4.8	68.5	1.0	17.7	.2	11590	.01	.01	.21
	C	--	45.5	54.5	--	5.2	74.2	1.1	19.2	.3	12560	.01	.01	.23
Knoblock bed, composite core bench sample, depth 136.4 to 151.3 ft														
D169478	A	30.9	29.4	34.5	5.2	6.8	47.3	0.7	39.9	0.1	8120	0.02	0.04	0.08
	B	--	42.6	49.9	7.5	4.8	68.4	1.0	18.1	.2	11750	.03	.06	.12
	C	--	46.1	53.9	--	5.2	73.9	1.0	19.7	.2	12700	.03	.07	.12
Knoblock bed, composite core bench sample, depth 151.3 to 166.3 ft														
D169479	A	30.1	29.0	35.1	5.8	6.7	47.9	0.7	38.8	0.1	8240	0.01	0.01	0.10
	B	--	41.5	50.3	8.2	4.8	68.6	1.0	17.2	.2	11800	.01	.01	.15
	C	--	45.3	54.7	--	5.2	74.7	1.0	18.9	.2	12850	.01	.01	.16
Knoblock bed, composite core bench sample, depth 166.3 to 181.3 ft														
D169480	A	29.7	27.9	35.3	7.1	6.5	47.1	0.7	38.4	0.2	8090	0.00	0.06	0.14
	B	--	39.6	50.4	10.0	4.6	66.9	1.0	17.2	.3	11500	.00	.08	.20
	C	--	44.1	55.9	--	5.1	74.4	1.1	19.1	.3	12790	.00	.09	.23
Flowers-Goodale bed, composite core bench sample, depth 289.2 to 299.2 ft														
D169725	A	28.8	27.8	36.4	7.0	6.5	48.1	0.8	37.2	0.4	8220	0.01	0.07	0.37
	B	--	39.0	51.1	9.9	4.6	67.5	1.1	16.3	.6	11550	.01	.10	.51
	C	--	43.3	56.7	--	5.1	75.0	1.2	18.0	.7	12830	.01	.11	.57

Table 4 (cont)

Table 4.--Proximate, ultimate, Btu and forms of sulfur analyses of samples of the Knoblock and Flowers-Goodale coal beds in Drill Hole 103, Tongue River Member of the Fort Union Formation (Paleocene age), Willow Crossing quadrangle, Powder River County, Montana. (All analyses except Btu are in percent. Original moisture content may be slightly more than shown because samples were collected and transported in plastic bags to avoid metal contamination. Form of analyses: A, as received; B, moisture free; C, moisture and ash free. All analyses by Coal Analysis Section, U.S. Bureau of Mines, Pittsburgh, Pa.)

SAMPLE NO.	FORM OF ANALYSIS	PROXIMATE ANALYSIS				ULTIMATE ANALYSIS					BTU VALUE	FORMS OF SULFUR		
		Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur		Sulfate	Pyritic	Organic
Knoblock bed, composite core bench sample, depth 128.5 to 141.8 ft														
D169719	A	31.4	28.3	34.7	5.6	6.8	46.4	0.8	40.2	0.2	7880	0.01	0.05	0.11
	B	--	41.3	50.6	8.1	4.8	67.6	1.1	18.2	.2	11500	.01	.08	.16
	C	--	44.9	55.1	--	5.3	73.7	1.2	19.5	.3	12520	.01	.09	.17
Knoblock bed, composite core bench sample, depth 141.8 to 156.7 ft														
D169720	A	33.5	28.1	34.3	4.1	6.9	46.0	0.6	42.2	0.2	7910	0.03	0.07	0.07
	B	--	42.3	51.5	6.2	4.8	69.3	1.0	18.5	.2	11900	.04	.10	.10
	C	--	45.1	54.9	--	5.1	73.8	1.0	19.8	.3	12680	.05	.11	.11
Knoblock bed, composite core bench sample, depth 156.7 to 171.7 ft														
D169721	A	26.6	31.0	37.2	5.2	6.5	50.6	0.7	36.8	0.2	8710	0.01	0.03	0.13
	B	--	42.2	50.7	7.1	4.9	68.9	.9	18.0	.2	11860	.01	.05	.18
	C	--	45.4	54.6	--	5.2	74.2	1.0	19.3	.3	12770	.01	.05	.20
Knoblock bed, composite core bench sample, depth 171.2 to 186.7 ft														
D169722	A	26.8	29.0	38.3	5.9	6.4	50.2	0.7	36.6	0.2	8570	0.01	0.04	0.14
	B	--	39.7	52.3	8.0	4.6	68.6	1.0	17.5	.3	11700	.01	.06	.20
	C	--	43.1	56.9	--	5.0	74.6	1.1	19.0	.3	12720	.01	.06	.21

Table 4 (cont)

Table 4.--Proximate, ultimate, Btu and forms of sulfur analyses of samples of the Knoblock and Flowers-Goodale coal beds in Drill Hole 104, Tongue River Member of the Fort Union Formation (Paleocene age), Willow Crossing quadrangle, Powder River County, Montana. (All analyses except Btu are in percent. Original moisture content may be slightly more than shown because samples were collected and transported in plastic bags to avoid metal contamination. Form of analyses: A, as received; B, moisture free; C, moisture and ash free. All analyses by Coal Analysis Section, U.S. Bureau of Mines, Pittsburgh, Pa.)

SAMPLE NO.	FORM OF ANALYSIS	PROXIMATE ANALYSIS				ULTIMATE ANALYSIS					BTU VALUE	FORMS OF SULFUR		
		Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur		Sulfate	Pyritic	Organic
Knoblock bed, composite core bench sample, depth 128.9 to 143.9 ft														
D170249	A	29.0	29.1	37.9	4.0	6.7	49.8	0.7	38.6	0.2	8420	0.01	0.07	0.11
	B	--	41.0	53.4	5.6	4.8	70.1	1.0	18.2	.3	11850	.01	.10	.16
	C	--	43.4	56.6	--	5.1	74.3	1.1	19.2	.3	12550	.01	.11	.17
Knoblock bed, composite core bench sample, depth 143.9 to 158.9 ft														
D170250	A	29.3	29.4	36.8	4.5	6.6	49.3	0.7	38.7	0.2	8400	0.01	0.08	0.10
	B	--	41.6	52.0	6.4	4.7	69.8	1.0	17.8	.3	11880	.01	.11	.14
	C	--	44.5	55.5	--	5.0	74.5	1.0	19.2	.3	12690	.01	.12	.15
Knoblock bed, composite core bench sample, depth 158.9 to 173.9 ft														
D170251	A	28.2	29.8	35.7	6.3	6.4	48.7	0.7	37.7	0.2	8350	0.01	0.07	0.11
	B	--	41.4	49.8	8.8	4.6	67.8	1.0	17.5	.3	11620	.01	.09	.16
	C	--	45.4	54.6	--	5.0	74.3	1.0	19.4	.3	12750	.01	.10	.17
Knoblock bed, composite core bench sample, depth 173.9 to 188.9 ft														
D170252	A	29.1	28.5	37.0	5.4	6.5	48.9	0.7	38.3	0.2	8280	0.02	0.05	0.13
	B	--	40.3	52.1	7.6	4.6	69.0	.9	17.6	.3	11680	.02	.07	.18
	C	--	43.6	56.4	--	5.0	74.7	1.0	19.0	.3	12640	.02	.07	.19

Table 4.--Proximate, ultimate, Btu and forms of sulfur analyses of samples of the Knoblock and Flowers-Goodale coal beds in Drill Hole 105, Tongue River Member of the Fort Union Formation (Paleocene age), Willow Crossing quadrangle, Powder River County, Montana. (All analyses except Btu are in percent. Original moisture content may be slightly more than shown because samples were collected and transported in plastic bags to avoid metal contamination. Form of analyses: A, as received; B, moisture free; C, moisture and ash free. All analyses by Coal Analysis Section, U.S. Bureau of Mines, Pittsburgh, Pa.)

SAMPLE NO.	FORM OF ANALYSIS	PROXIMATE ANALYSIS				ULTIMATE ANALYSIS					BTU VALUE	FORMS OF SULFUR		
		Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur		Sulfate	Pyritic	Organic
Knoblock bed, composite core bench sample, depth 200.8 to 210.8 ft														
D170197	A	35.1	26.4	31.3	7.2	6.9	43.3	0.7	41.7	0.2	7270	0.01	0.07	0.09
	B	--	40.6	48.3	11.1	4.6	66.6	1.2	16.2	.3	11190	.01	.11	.13
	C	--	45.6	54.4	--	5.1	74.9	1.3	18.4	.3	12580	.01	.13	.15
Knoblock bed, composite core bench sample, depth 210.8 to 225.8 ft														
D170198	A	32.3	27.6	34.0	6.1	6.8	45.9	0.7	40.4	0.1	7860	0.07	0.06	0.01
	B	--	40.8	50.2	9.0	4.7	67.9	1.1	17.1	.2	11620	.10	.09	.01
	C	--	44.9	55.1	--	5.1	74.6	1.2	18.9	.2	12770	.11	.10	.01
Knoblock bed, composite core bench sample, depth 225.8 to 240.8 ft														
D170199	A	32.6	27.8	33.5	6.1	6.9	46.2	0.7	39.9	0.2	7840	0.01	0.02	0.12
	B	--	41.2	49.8	9.0	4.8	68.6	1.0	16.4	.2	11640	.01	.04	.18
	C	--	45.3	54.7	--	5.3	75.4	1.1	18.0	.2	12790	.01	.04	.19
Knoblock bed, composite core bench sample, depth 240.8 to 255.8 ft														
D170200	A	32.8	26.7	34.7	5.8	6.7	46.2	0.6	40.5	0.2	7830	0.01	0.09	0.08
	B	--	39.7	51.7	8.6	4.6	68.7	.9	16.9	.3	11660	.01	.14	.12
	C	--	43.5	56.5	--	5.0	75.3	1.0	18.4	.3	12770	.01	.15	.13
Knoblock bed, composite core bench sample, depth 255.8 to 265.8 ft														
D170201	A	33.6	27.0	34.9	4.5	6.8	46.3	0.6	41.5	0.3	7920	0.01	0.05	0.26
	B	--	40.7	52.5	6.8	4.6	69.6	1.0	17.5	.5	11920	.01	.07	.39
	C	--	43.6	56.4	--	4.9	74.7	1.0	18.9	.5	12790	.01	.07	.42
Flowers-Goodale bed, composite core bench sample, depth 385.2 to 394.0 ft														
D170202	A	27.5	26.2	34.4	11.9	6.0	45.8	0.7	35.0	0.6	7790	0.01	0.15	0.43
	B	--	36.1	47.5	16.4	4.1	63.1	1.0	14.6	.8	10740	.01	.21	.59
	C	--	43.2	56.8	--	4.9	75.6	1.2	17.3	1.0	12850	.01	.25	.71

Table 4 (cont)

Table 4.--Continued--Proximate, ultimate, Btu and forms of sulfur analyses of samples of the Knoblock coal bed in Drill Hole 106, Tongue River Member of the Fort Union Formation (Paleocene age), Willow Crossing quadrangle, Powder River County, Montana. (All analyses except Btu are in percent. Original moisture content may be slightly more than shown because samples were collected and transported in plastic bags to avoid metal contamination. Form of analyses: A, as received; B, moisture free; C, moisture and ash free. All analyses by Coal Analyses Section, U.S. Bureau of Mines, Pittsburgh, Pa.)

SAMPLE NO.	FORM OF ANALYSIS	PROXIMATE ANALYSIS				ULTIMATE ANALYSIS					BTU VALUE	FORMS OF SULFUR		
		Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur		Sulfate	Pyritic	Organic
Knoblock bed, composite core bench sample, depth 169.5 to 184.5 ft														
K-52805	A	30.9	29.0	34.9	5.2	6.5	47.8	0.8	39.5	0.2	8110	0.01	0.06	0.12
	B	--	42.0	50.4	7.6	4.4	69.2	1.2	17.3	.3	11750	.01	.08	.17
	C	--	45.5	54.5	--	4.8	74.9	1.2	18.8	.3	12710	.01	.08	.19
Knoblock bed, composite core bench sample, depth 184.5 to 199.5 ft														
K-52806	A	29.7	28.6	37.2	4.5	6.7	49.1	0.7	38.8	0.2	8400	0.02	0.08	0.09
	B	--	40.7	52.9	6.4	4.8	69.9	1.0	17.6	.3	11950	.02	.11	.12
	C	--	43.5	56.5	--	5.2	74.7	1.1	18.7	.3	12770	.02	.12	.13
Knoblock bed, composite core bench sample, depth 199.5 to 214.5 ft														
K-52807	A	28.9	30.7	35.6	4.8	6.7	47.7	0.7	40.0	0.1	8190	0.01	0.07	0.07
	B	--	43.2	50.0	6.8	4.9	67.0	1.0	20.1	.2	11510	.01	.10	.10
	C	--	46.4	53.6	--	5.3	71.9	1.1	21.5	.2	12350	.01	.10	.10
Knoblock bed, composite core bench sample, depth 214.5 to 228.1 ft														
K-52608	A	26.8	31.3	36.8	5.1	6.6	48.9	0.7	38.4	0.3	8410	0.01	0.13	0.12
	B	--	42.8	50.3	6.9	4.9	66.9	1.0	19.9	.4	11490	.01	.18	.16
	C	--	46.0	54.0	--	5.3	71.8	1.0	21.5	.4	12350	.01	.20	.17

Table 4.--Continued--Proximate, ultimate, Btu and forms of sulfur analyses of samples of the Knoblock coal bed in Drill Hole 107, Tongue River Member of the Fort Union Formation (Paleocene age), Willow Crossing quadrangle, Powder River County, Montana. (All analyses except Btu are in percent. Original moisture content may be slightly more than shown because samples were collected and transported in plastic bags to avoid metal contamination. Form of analyses: A, as received; B, moisture free; C, moisture and ash free. All analyses by Coal Analyses Section, U.S. Bureau of Mines, Pittsburgh, Pa.)

SAMPLE NO.	FORM OF ANALYSIS	PROXIMATE ANALYSIS				ULTIMATE ANALYSIS					BTU VALUE	FORMS OF SULFUR		
		Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur		Sulfate	Pyritic	Organic
		Knoblock bed, composite core bench sample, depth 54.2 to 64.2 ft												
K-52809	A	26.0	32.5	34.7	6.8	6.5	48.3	0.8	37.4	0.2	8310	0.01	0.11	0.13
	B	--	43.9	47.0	9.1	4.9	65.2	1.1	19.4	.3	11220	.01	.15	.17
	C	--	48.3	51.7	--	5.4	71.8	1.2	21.2	.4	12350	.01	.16	.19
		Knoblock bed, composite core bench sample, depth 64.2 to 79.2 ft												
K-52810	A	31.5	29.1	34.8	4.6	6.8	47.0	0.7	40.7	0.2	8120	0.01	0.11	0.06
	B	--	42.5	50.8	6.7	4.8	68.6	1.1	18.5	.3	11850	.01	.16	.09
	C	--	45.6	54.4	--	5.2	73.5	1.1	19.9	.3	12710	.01	.17	.10
		Knoblock bed, composite core bench sample, depth 79.2 to 94.2 ft												
K-52811	A	29.1	31.2	35.3	4.4	6.7	49.3	0.7	38.7	0.02	8480	0.01	0.07	0.13
	B	--	44.0	49.8	6.2	4.9	69.5	1.0	18.1	.03	11970	.01	.10	.19
	C	--	47.0	53.0	--	5.2	74.2	1.1	19.2	.03	12770	.01	.11	.20
		Knoblock bed, composite core bench sample, depth 94.2 to 109.2 ft												
K-52812	A	28.7	30.6	35.4	5.3	6.6	49.0	0.7	38.2	0.02	8420	0.00	0.08	0.10
	B	--	42.8	49.8	7.4	4.7	68.7	1.0	18.0	.02	11810	.00	.11	.14
	C	--	46.3	53.7	--	5.1	74.2	1.1	19.3	.03	12760	.00	.12	.15
		Knoblock bed, composite core bench sample, depth 109.2 to 120.3 ft												
K-52813	A	30.4	29.3	35.9	4.4	6.7	48.9	0.7	39.0	0.3	8390	0.01	0.12	0.15
	B	--	42.1	51.5	6.4	4.8	70.2	1.0	17.2	.4	12050	.01	.18	.22
	C	--	44.9	55.1	--	5.1	74.9	1.1	18.5	.4	12870	.01	.19	.24

Estimation and Classification of Coal Resources

Preparation of a coal resource estimate involves certain procedures and definitions that have been established in an attempt to standardize, insofar as possible, coal resource appraisals in the United States. As used in this report, the term "coal resource" designated the estimated quantity of coal in the ground.

Tabulation of Estimated Coal Resources

Table 5 summarizes the estimated coal resources in the Knoblock coalbed in the Otter Creek EMRIA site and the surrounding area. In accordance with conventions adopted by the U.S. Geological Survey and the U.S. Bureau of Mines, the resources in the Otter Creek study site are classed as "identified-subeconomic resources"--that is, specific bodies of coal whose location, quality, and quantity are known from geologic evidence supported by engineering measurements with respect to the demonstrated category, and that are presently classed as subeconomic because the estimated tonnage of coal is in beds that are not presently classed as reserves, but may become so as a result of changes in economic and legal conditions.

No estimates are presented for the Flowers-Goodale bed in the area because the focus of the present study is on coal resources that are potentially recoverable by surface-mining methods.

Table 5.--Estimated identified coal resources in the Knoblock bed in the area around and including the Otter Creek study site. 1/
(in thousands of tons.)

	Measured resources	Indicated resources	Total
Otter Creek study site (sec. 2 T. 4 S., R. 45 E. and sec. 26 and 34, T. 3 S., R. 45 E.	88,652	37,210	125,862
Area surrounding Otter Creek study site	--	192,422	192,422
Total Identified resources	88,652	229,632	318,284

1/ Area of about 3 square miles bounded by Home Creek, Otter Creek, and Threemile Creek, and 106° 7-1/2' West Longitude.

All of the estimated identified coal resources shown in table 5 fall into a category called Reserve Base, which is defined as that portion of the identified coal resource from which reserves are calculated. Reserves in the strict sense used here are defined as "that portion of the identified coal resource that can be economically and legally mined at the time of determination--also referred to as Recoverable

Reserve. The reserve is derived by applying a recoverability factor to that component of the identified coal resource designated as the Reserve Base."

Recoverability

The recoverability factor is "the percentage of total tons of coal producible from a given area in relation to the total tonnage estimated to be in place in the ground."

Recoverability determinations can be made (1) by using mine maps, (2) from production versus reserve base estimates, or (3) by using an average recoverability factor based on past experience. All coal remaining in the ground after mining is completed is considered as lost in mining and includes coal that is (1) left to support mine roofs, (2) too thin to mine, (3) left unmined beneath rivers, lakes, highways, and legal reservations, (4) left unmined around oil, gas, water, and disposal wells, (5) left unmined as barrier pillars adjacent to mine or property boundaries, and (6) left unmined because of environmental, safety, quality, or hydrologic considerations. Coal losses incurred during cleaning and preparation are not considered when determining recoverability. Recoverability determined in existing mined areas can be projected to similar unmined areas, assuming other conditions equal, to calculate reserves from reserve base. In the U.S. recoverability in underground mining ranges from 10 to 80 percent, depending on variables such as the thickness of coalbed, security of roof and floor rock, operator, and mining method, but nationally is about 50 percent. Recoverability for strip mining is locally as great as 90 percent, but studies indicate that nationally it also averages about 50 percent owing to barriers left to protect mine boundaries, to restrictions on highwalls, and to restrictions about mining near lakes, streams, railroads, highways, and farmed areas.

Resources Categorized by Degree of Geologic Assurance

Two categories according to degree of geologic assurance were used in the present study.

Measured - Tonnage of coal for which estimates of the quality and quantity have been computed, within a margin of error of less than 20 percent, from sample analyses and measurements from closely spaced and geologically well-known sample sites.

Indicated- Tonnage of coal for which estimates of the quality and quantity have been computed partly from sample analyses and measurements and partly from reasonable geologic projections.

The measured resources estimated for the Otter Creek EMRIA site and adjoining area are within 1/4 mile of points of information; the indicated resources are contained in bodies whose inner limits are 1/4 mile from points of information and whose outer limits are within 3/4 mile of points of information.

Characteristics used in Resource Evaluation

The coal characteristics that are commonly used in classifying coal resources are the rank, grade, and weight of the coal, the thickness and areal extent of the coalbeds, and the thickness of the overburden. The rank and grade of the coal sampled as part of this study have been discussed previously.

Weight

The weight of the coal ranges considerably with differences in rank and ash content. In areas where true specific gravities of the coals have not been determined, an average specific gravity value based on many determinations in other areas is used to express the weight of the coal for resource calculations. The average weight of subbituminous coal is taken as 1,770 tons per acre-foot--a specific gravity of 1.30.

Thickness of Beds

Because of the important relation of coalbed thickness to utilization potential, most coal resource estimates prepared by the U.S. Geological Survey are tabulated according to three thickness categories. For subbituminous coal the categories are: thin--2.5 to 5 feet; intermediate--5 to 10 feet; and thick--more than 10 feet. In the Otter Creek study site and surrounding area, all of the estimated resources in the Knoblock bed are in the thick category.

Thickness of Overburden

Coal resources are commonly divided into categories based on the thickness of overburden, in feet, as follows: 0-1,000, 1,000-2,000, and 2,000-3,000. For estimates of total resources and undiscovered resources--for example, an estimate for a complete coal basinal area--a depth of 6,000 feet may be used. However, most of the coal in the Knoblock bed in the Otter Creek EMRIA site and surrounding area is overlain by 200 feet or less of overburden and can be recovered by surface mining methods. Table 6 shows detailed and aggregate volume of overburden on the EMRIA site. Comparison of tables 5 and 6 indicates that the ratio of cubic yards of overburden to total estimated coal resources with less than 200 feet of overburden in the Otter Creek study site is about 2 cubic yards of overburden per ton of coal.

Summary of Resources

The Knoblock coalbed in the area around and including the Otter Creek study site--an area of about 2,975 acres--contains an estimated identified coal resources of about 318,284,000 tons. The Otter Creek study site

Table 6.--Quantity of overburden above the Knoblock bed in the Otter Creek Study site. (Overburden thickness 200 feet or less.)

Contour interval (ft.)	Acreage between 20 ft. contours		Average footage above Knoblock Coal		Square feet in acre	Cubic feet in cubic yard		Cubic yard overburden (thousands)
Sec 2 T. 4 S., R. 45 E.								
3,260 - 3,240	17.8	X	190	X	43,560	27	=	5,456,000
3,240 - 3,220	43.6	X	170	X	43,560	27	=	11,958,000
3,220 - 3,200	40.9	X	150	X	43,560	27	=	9,898,000
3,200 - 3,180	55.1	X	130	X	43,560	27	=	11,556,000
3,180 - 3,160	59.2	X	110	X	43,560	27	=	10,506,000
3,160 - 3,140	44.9	X	90	X	43,560	27	=	6,519,000
3,140 - 3,120	41.9	X	70	X	43,560	27	=	4,732,000
3,120 - 3,100	36.9	X	50	X	43,560	27	=	2,977,000
3,100 - 3,080	55.4	X	30	X	43,560	27	=	2,681,000
3,080 - 3,060	21.5	X	10	X	43,560	27	=	347,000
Totals	417.2							66,631,000
Sec 34 T. 3 S., R. 45 E.								
3,260 - 3,240	69.8	X	190	X	43,560	27	=	21,396,000
3,240 - 3,220	60.9	X	170	X	43,560	27	=	16,703,000
3,220 - 3,200	66.3	X	150	X	43,560	27	=	16,045,000
3,200 - 3,180	82.8	X	130	X	43,560	27	=	17,366,000
3,180 - 3,160	66.2	X	110	X	43,560	27	=	11,748,000
3,160 - 3,140	36.8	X	90	X	43,560	27	=	5,343,000
3,140 - 3,120	10.8	X	70	X	43,560	27	=	871,000
3,120 - 3,100	2.1	X	50	X	43,560	27	=	169,000
Totals	395.7							89,642,000
Sec 26, T. 3 S., R. 45 E.								
3,260 - 3,240	5.2	X	190	X	43,560	27	=	1,594,000
3,240 - 3,220	38.3	X	170	X	43,560	27	=	10,504,000
3,220 - 3,200	55.2	X	150	X	43,560	27	=	13,358,000
3,200 - 3,180	82.1	X	130	X	43,560	27	=	17,219,000
3,180 - 3,160	71.8	X	110	X	43,560	27	=	12,742,000
3,160 - 3,140	63.3	X	90	X	43,560	27	=	9,191,000
3,140 - 3,120	39.6	X	70	X	43,560	27	=	4,472,000
3,120 - 3,100	8.5	X	50	X	43,560	27	=	686,000
Totals	364.0							69,767,000
All Totals 1,117 acres in which overburden in 200 feet or less								226,039,000

per se--an area about 1,177 acres underlain by recoverable coal--contains an estimated identified coal resources of about 125,862,000 tons. All estimated coal resources in the Knoblock bed are categorized as measured and indicated resources and all but about 62,000,000 tons are at depths of less than 200 feet. The overall ratio of cubic yards of overburden to tons of coal in the area with 200 feet or less of overburden is about two cubic yards of overburden per ton of coal.

Trace Elements

Twenty-eight core samples of the Knoblock and Flowers-Goodale coalbeds and thirty-nine core samples of the rock sequence above and below the Knoblock were analyzed for the following constituents following the procedure shown on figure 4.

As an aid in solution of problems of coal utilization, the Geological Survey Analytical Laboratories routinely provide the following analytical determinations on all samples:

1. Proximate analysis for percent moisture, volatile matter, fixed carbon, and ash: Ultimate analysis for percent hydrogen, carbon, nitrogen, oxygen, and sulfur; and, forms-of-sulfur analysis for percent sulfate-sulfur, pyritic sulfur, and organic sulfur.

2. Major composition of the ash of coal--percent ash, SiO_2, Al_2O_3, Na_2O, K_2O, CaO, MgO, Fe_2O_3, P_2O_5, Cl, MnO, TiO_2, and SO_3.

3. Trace element composition of coal

    a. Individual quanitative determinations--ppm As, Cd, Cu, F, Hg, Li, Pb, Sb, Se, Th, U, and Zn.

    b. Semiquantitative spectrographic analysis--ppm of 20-30 elements detected by this method.

Results of the analytical determinations are listed here in tables 7, 8, 9, and 10.

Table 11 compares analyses of twenty-four samples of the Knoblock coalbed in the Otter Creek area to sixty-seven samples of subbituminous coals from 7 mines and 12 drill holes in the Powder River Basin of Wyoming and Montana (Swanson, Huffman, and Hamilton, 1974). The lower heat value (Btu), greater moisture and oxygen content, and smaller fixed carbon content of the Knoblock coal as compared to the average of subbituminous coals in the Powder River Basin is a direct reflection of the lower range (lesser degree of metamorphism) of the Knoblock coal. There are no other significant differences shown by the comparison in table 11.

Figure 4

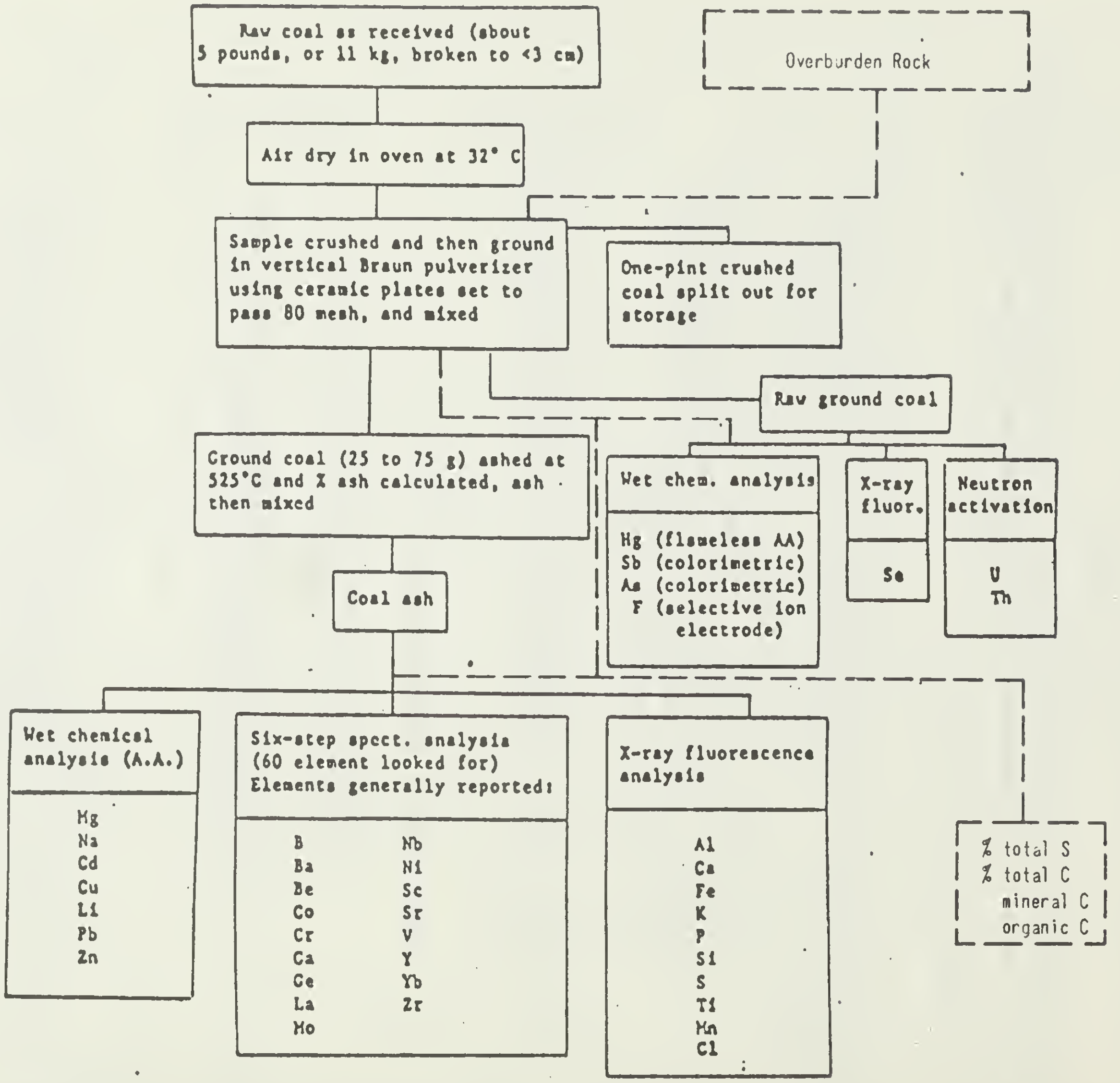

Raw coal as received (about 5 pounds, or 11 kg, broken to <3 cm)
Overburden Rock
Air dry in oven at 32° C
Sample crushed and then ground in vertical Braun pulverizer using ceramic plates set to pass 80 mesh, and mixed
One-pint crushed coal split out for storage
Raw ground coal
Ground coal (25 to 75 g) ashed at 525°C and % ash calculated, ash then mixed
Wet chem. analysis
Hg (flameless AA)
Sb (colorimetric)
As (colorimetric)
F (selective ion electrode)
X-ray fluor.
Se
Neutron activation
U
Th
Coal ash
Wet chemical analysis (A.A.)
Hg
Na
Cd
Cu
Li
Pb
Zn
Six-step spect. analysis (60 element looked for) Elements generally reported:
B
Ba
Be
Co
Cr
Ga
Ge
La
Mo
Nb
Ni
Sc
Sr
V
Y
Yb
Zr
X-ray fluorescence analysis
Al
Ca
Fe
K
P
Si
S
Ti
Mn
Cl
% total S
% total C
mineral C
organic C

Figure 4. Sequence of sample preparation and analysis.

Table 7

Table 7.--Major and minor oxide and trace element composition of the laboratory ash of twenty-eight coal samples of core from Otter Creek, Montana. (Values are in either percent or parts per million. The coals were ashed at 525°C. L after a value means less than the value shown, N means not detected, and B means not determined. S after the element title means that the values listed were determined by semiquantitative spectrographic analysis. The spectrographic results are to be identified with geometric brackets whose boundaries are 1.2, 0.83, 0.56, 0.38, 0.26, 0.18, 0.12, etc., but are reported arbitrarily as mid-points of those brackets, 1.0, 0.7, 0.5, 0.3, 0.2, 0.15, 0.1, etc. The precision of the spectrographic data is approximately one bracket at 68 percent, or two brackets at 95 percent confidence.

Sample	Field No.	Thickness	Ash %	Al_2O_3 %	CaO %	Fe_2O_3%	MgO%	Na_2O%	K_2O %	SO_3 %	SiO_2%	Cl%
Knoblock bed, BurRec DH 74-101 (NESW sec. 34, T. 3 S., R. 45 E.)												
D169028	74-101-1	1.6	13.4	17.	11.	3.2	5.0	3.3	1.0	9.3	45.	0.10L
D169029	74-101-2	5.	12.9	18.	11.	3.6	3.2	3.5	1.3	4.4	45.	.10L
D169030	74-101-3	5.	6.10	16.	21.	3.6	3.9	7.5	.47	7.8	24.	.10L
D169031	74-101-4	5.	7.00	17.	17.	3.6	3.5	6.5	1.0	5.6	34.	.10L
D169032	74-101-5	5.	6.90	16.	17.	3.5	3.8	6.8	.78	6.8	33.	.10L
D169033	74-101-6	5.	8.50	18.	16.	3.4	3.1	5.6	.70	10.	33.	.10L
D169034	74-101-7	4.8	7.60	19.	15.	5.3	3.0	5.7	.26	18.	30.	.10L
D169035	74-101-8	5.	5.30	10.	21.	4.3	4.2	8.0	.49	9.1	25.	.10L
D169036	74-101-9	5.	12.4	7.3	8.4	1.5	1.8	3.2	.10	3.2	69.	.10L
D169037	74-101-10	5.	7.80	14.	13.	2.6	2.6	5.4	.092	7.5	47.	.10L
D169038	74-101-11	5.	6.50	12.	17.	3.0	3.4	6.8	.035	11.	39.	.10L
D169039	74-101-12	5.	6.90	13.	15.	3.0	3.0	6.3	.11	16.	39.	.10L
D169040	74-101-13	4.4	12.0	17.	7.8	2.8	2.2	3.7	1.5	12.	52.	.10L
Knoblock bed, BurRec DH 74-102 (NWSE sec. 26, T. 3 S., R. 45 E.)												
D169437	74-102-1	4.	9.20	20.	14.	3.2	5.1	1.4	0.68	7.5	40.	0.10L
D169438	74-102-2	4.7	6.94	16.	18.	4.5	6.4	2.1	1.1	6.8	30.	.10L
D169439	74-102-3	5.	9.46	16.	17.	3.9	4.9	1.6	1.4	5.0	34.	.10L
D169440	74-102-4	4.9	7.64	17.	18.	3.6	5.2	2.3	1.2	5.0	33.	.10L
D169441	74-102-5	5.	8.44	21.	17.	2.6	4.2	1.7	.78	4.4	34.	.10L
D169442	74-102-6	5.	8.68	21.	17.	2.3	4.1	1.7	.61	5.1	34.	.10L
D169443	74-102-7	5.	6.06	17.	22.	3.2	5.2	2.9	.70	6.1	27.	.10L
D169444	74-102-8	5.	7.90	15.	18.	2.3	4.0	1.9	.32	6.1	38.	.10L
D169445	74-102-9	5.	10.7	17.	16.	2.7	3.4	1.6	.84	5.4	42.	.10L
D169446	74-102-10	5.	8.96	12.	22.	3.1	3.4	1.7	.45	7.3	35.	.10L
D169447	74-102-11	5.	11.2	14.	11.	2.0	2.7	1.5	.37	6.7	53.	.10L
Flowers-Goodale bed, BurRec DH 74-101												
D169475	74-101-14	4.5	8.44	24.	15.	3.5	2.5	4.5	0.15	11.	37.	0.10L
D169476	74-101-15	5.2	6.78	22.	16.	4.4	2.6	5.6	.32	18.	30.	.10L
Flowers-Goodale bed, BurRec DH 74-102												
D169723	74-102-12	5.	11.0	24.	9.6	4.4	1.9	3.7	1.1	14.	43.	0.10L
D169724	74-102-13	5.	6.30	17.	19.	4.4	3.1	6.4	.33	16.	26.	.10L

Table 7 (cont)

Table 7.

SAMPLE	MnO %	P_2O_5 %	TiO_2 %	Cd PPM	Cu PPM	Li PPM	Pb PPM	Zn PPM	B PPM-S	Ba PPM-S
Knoblock bed, BurRec DH 74-101 (NESW sec. 34, T. 3 S., R. 45 E.)										
D169028	0.052	0.10L	0.54	1.L	70.	72.	70.	160.	300	3000
D169029	.056	.10L	.51	1.L	60.	104.	90.	160.	300	3000
D169030	.046	.10L	.38	1.L	53.	66.	50.	94.	1000	3000
D169031	.033	.10L	.52	1.L	62.	60.	55.	156.	1000	3000
D169032	.031	.10L	.54	1.L	68.	70.	80.	142.	700	3000
D169033	.034	.10L	.92	1.L	114.	114.	70.	176.	700	5000
D169034	.020L	.10L	1.0	1.L	92.	135.	70.	136.	1000	3000
D169035	.029	.10L	.40	1.L	64.	45.	85.	214.	1000	7000
D169036	.020L	.10L	.86	1.L	48.	52.	40.	96.	500	1000
D169037	.020L	.10L	.91	1.L	72.	100.	60.	76.	1000	2000
D169038	.020	.10L	.53	1.L	56.	74.	40.	72.	1000	3000
D169039	.021	.10L	.84	1.L	102.	60.	50.	80.	1000	1500
D169040	.020L	.10L	.71	1.L	98.	53.	40.	100.	700	1500
Knoblock bed, BurRec DH 74-102 (NWSE sec. 26, T. 3 S., R. 45 E.)										
D169437	0.020L	0.10L	0.71	1.L	58.	114.	70.	97.	1000	3000
D169438	.046	.10L	.43	1.L	56.	36.	55.	119.	1000	7000
D169439	.052	.10L	.49	1.L	48.	36.	55.	122.	500	15000
D169440	.033	.10L	.50	1.L	56.	42.	460.	1180.	700	7000
D169441	.020L	.10L	.92	1.L	66.	118.	70.	79.	700	1500
D169442	.020L	.10L	1.1	1.L	106.	116.	50.	67.	700	2000
D169443	.020L	.10L	.55	1.L	66.	106.	50.	98.	1000	10000
D169444	.020L	.10L	.85	1.L	94.	84.	50.	74.	700	5000
D169445	.021	.10L	.75	1.L	70.	90.	65.	122.	700	5000
D169446	.060	.10L	.58	1.L	72.	36.	40.	62.	1000	3000
D169447	.020L	.10L	1.2	1.L	102.	60.	40.	57.	700	2000
Flowers-Goodale bed, BurRec DH 74-101										
D169475	0.040	0.10L	0.65	1.L	94.	74.	60.	60.	1000	7000
D169476	.041	.10L	.71	1.L	104.	62.	40.	69.	1500	7000
Flowers-Goodele bed, BurRec DH 74-102										
D169723	0.030	0.10L	0.64	1.L	92.	78.	45.	129.	700	3000
D169724	.034	.10L	.55	1.L	92.	46.	55.	67.	1500	7000

Table 7

SAMPLE	Be PPM-S	Co PPM-S	Cr PPM-S	Ga PPM-S	Ge PPM-S	La PPM-S	Mo PPM-S	Nb PPM-S	Ni PPM-S	Sc PPM-S	S
Knoblock bed, BurRec DH 74-101 (NESW sec. 34, T. 3 S., R. 45 E.)											
D169028	20	15	30	20	70	70	7	30	20	15	
D169029	N	7 L	30	30	N	N	7	20	15	10	
D169030	3	7 L	30	20	N	70	7	20 L	20	15	
D169031	N	7 L	30	30	N	70	7	20 L	20	10	
D169032	N	7 L	30	20	N	N	70	20 L	15	10	
D169033	N	7 L	50	30	N	N	7	20 L	10	10	
D169034	N	7 L	30	30	N	N	7	20 L	10	10	
D169035	N	7 L	30	15	N	N	10	20 L	15	10 L	
D169036	N	N	20	15	N	N	10	20	10 L	N	
D169037	N	N	30	30	N	N	7 L	20	10 L	10	
D169038	N	N	20	15	N	70	10	20 L	10	10	
D169039	N	N	20	20	N	70	7 L	20 L	10	10 L	
D169040	15	10	70	30	N	70	7	20	15	15	
Knoblock bed, BurRec DH 74-102 (NWSE sec. 26, T. 3 S., R. 45 E.)											
D169437	3	N	30	30	N	70	7	20	10	10	
D169438	3	7 L	30	15	N	70	7	N	15	10	
D169439	N	7 L	30	20	N	70	7	N	15	10	
D169440	N	7 L	50	50	N	70	70	20 L	15	15	
D169441	N	7 L	30	30	N	70	7 L	20 L	15	15	
D169442	N	7 L	30	30	N	70	7 L	20 L	10	15	
D169443	N	7 L	30	30	N	70	7	20 L	15	10	
D169444	N	N	30	30	N	70	N	20 L	10	15	
D169445	N	N	30	30	N	N	7 L	20 L	10 L	10	
D169446	N	7 L	30	20	N	N	7	N	10 L	10	
D169447	N	N	30	30	N	N	N	20	10	10	
Flowers-Goodale bed, BurRec DH 74-101											
D169475	10	7 L	30	30	N	70	10	20 L	15	20	
D169476	20	10	50	50	N	70	15	20	15	30	
Flowers-Goodale bed, BurRec DH 74-102											
D169723	10	10	30	50	N	N	15	20 L	20	20	
D169724	10	10	20	30	N	70	7	20 L	10	15	

Table 7

SAMPLE	V PPM-S	Y PPM-S	Yb PPM-S	Zr PPM-S
Knoblock bed, BurRec DH 74-101 (NESW sec. 34, T. 3 S., R. [illegible])				
D169028	70	50	5	200
D169029	70	20	3	150
D169030	70	30	3	150
D169031	70	20	3	150
D169032	70	20	2	150
D169033	70	20 L	2 L	200
D169034	70	20 L	2 L	150
D169035	50	20	2	100
D169036	20	20	2	300
D169037	70	20	2	200
D169038	50	20	2	150
D169039	50	20 L	2	150
D169040	150	30	3	150
Knoblock bed, BurRec DH 74-102 (NWSE sec. 26, T. 3 S., R. 45 E.)				
D169437	50	20	2	200
D169438	50	30	2	150
D169439	70	20	2	150
D169440	70	20	2	150
D169441	100	20	2	200
D169442	70	20	2	200
D169443	70	20	2	150
D169444	70	20	2	200
D169445	70	20	2	200
D169446	70	20	2	200
D169447	70	20	2	300
Flowers-Goodale bed, BurRec DH 74-101				
D169475	70	50	5	200
D169476	100	50	5	200
Flowers-Goodale bed, BurRec DH 74-102				
D169723	100	30	3	200
D169724	50	30	3	150

Table 8

Table 8 .Content of seven trace elements in twenty-eight coal samples from Otter Creek, Montana.[f] (Analyses on air-dried (32°C.) coal. All values are in parts per million. L after a value means less than the value shown, B means not determined.

Sample	Field No.	Thickness	As PPM	F PPM	Hg PPM	Sb PPM	Se PPM	Th PPM	U PPM
Knoblock bed, BurRec DH 74-101 (NESW sec. 34, T. 3 S., R. 45 E.)									
D169028	74-101-1	1.6	3.	70.	0.12	2.3	0.3	3.1	1.2
D169029	74-101-2	5.	1.	80.	.02	.2	.2	4.0	1.3
D169030	74-101-3	5.	1.	40.	.01	.1	.2	B	.3
D169031	74-101-4	5.	2.	50.	.03	.2	.2	2.3	.3
D169032	74-101-5	5.	1.	45.	.01	.2	.2	1.9	.4
D169033	74-101-6	5.	1.	45.	.02	.3	.1	2.2	.7
D169034	74-101-7	4.8	12.	35.	.01	.5	.3	2.3	.7
D169035	74-101-8	5.	1.	35.	.01	.1	.4	B	.1 <
D169036	74-101-9	5.	1.L	30.	.02	.2	.4	3.6	.6
D169037	74-101-10	5.	1.L	30.	.01	.3	.3	2.9	1.1
D169038	74-101-11	5.	1.L	25.	.01	.1	.2	1.9	.4
D169039	74-101-12	5.	1.L	25.	.04	.2	.3	B	.6
D169040	74-101-13	4.4	2.	85.	.06	.7	.5	2.6	1.2
Knoblock bed, BurRec DH 74-102 (NWSE sec. 26, T. 3 S., R. 45 E.)									
D169437	74-102-1	4.	1.	55.	0.05	0.5	0.5	7.3	1.8
D169438	74-102-2	4.7	1.	50.	.05	.2	.2	2.3	.2
D169439	74-102-3	5.	1.	65.	.04	.3	.6	2.6	.4
D169440	74-102-4	4.4	1.	60.	.06	.3	.6	3.3	.1 <
D169441	74-102-5	5.	1.	50.	.05	.5	.4	7.4	.7
D169442	74-102-6	5.	1.	70.	.32	.5	.9	3.8	1.0
D169443	74-102-7	5.	1.	45.	.06	.4	.4	2.1	.3
D169444	74-102-8	5.	1.	30.	.05	.2	.6	2.9	.8
D169445	74-102-9	5.	1.	50.	.05	.3	.5	5.3	.9
D169446	74-102-10	5.	1.	45.	.05	.2	.6	2.3	.6
D169447	74-102-11	5.	1.	50.	.08	.4	1.0	B	1.0
Flowers-Goodale bed, BurRec DH 74-101									
D169475	74-101-14	4.5	2.	25.	0.06	0.8	0.6	B	1.5
D169476	74-101-15	5.2	2.	30.	.05	1.0	.7	3.1	1.0
Flowers-Goodale bed, BurRec DH 74-102									
D169723	74-102-12	5.	4.	45.	0.11	1.4	0.4	4.0	2.6
D169724	74-102-13	5.	1.	40.	.04	.4	.2	1.9	.6

Table 9.--Major, minor and trace element composition of twenty-eight coal samples from Otter Creek, Montana, reported on whole-coal basis. (Values are in either percent or parts per million. Al, Ca, Fe, Mg, Na, K, Si, Cl, Mn, P, Ti, Cd, Cu, Li, Pb, and Zn values were calculated from analyses of ash. As, F, Hg, Sb, Se, Th and U values are from direct determinations on air dried (32°C.) coal. The remaining analyses were calculated from spectrographic determinations on ash. L after a value means less than the value shown, N means not detected, and B means not determined.)

Sample	Field No.	Thickness (ft)	Al %	Ca %	Fe %	Mg %	Na %	K %	Si %	Cl %	Mn PPM	P PPM
Knoblock bed, BurRec DH 74-101 (NESW sec. 34, T. 3 S., R. 45 E.)												
D169028	74-101-1	1.6	1.2	1.0	0.30	0.40	0.32	0.11	2.8	0.01L	54.	58.L
D169029	74-101-2	5.	1.2	1.1	.32	.25	.34	.14	2.7	.01L	56.	56.L
D169030	74-101-3	5.	.53	.90	.15	.14	.34	.024	.69	.01L	22.	27.L
D169031	74-101-4	5.	.62	.84	.17	.15	.34	.058	1.1	.01L	18.	31.L
D169032	74-101-5	5.	.60	.85	.17	.16	.35	.045	1.1	.01L	16.	30.L
D169033	74-101-6	5.	.79	.99	.20	.16	.35	.049	1.3	.01L	22.	37.L
D169034	74-101-7	4.8	.75	.83	.28	.14	.32	.017	1.1	.01L	12.L	33.L
D169035	74-101-8	5.	.29	.80	.16	.13	.31	.022	.63	.01L	12.	23.L
D169036	74-101-9	5.	.48	.75	.13	.13	.30	.011	4.0	.01L	19.L	54.L
D169037	74-101-10	5.	.57	.74	.14	.12	.31	.016	1.7	.01L	12.L	34.L
D169038	74-101-11	5.	.42	.79	.14	.13	.33	.002	1.2	.01L	10.	28.L
D169039	74-101-12	5.	.46	.74	.14	.13	.32	.006	1.3	.01L	11.	30.L
D169040	74-101-13	4.4	1.1	.66	.23	.16	.33	.15	2.9	.01L	19.L	52.L
Knoblock bed, BurRec DH 74-102 (NWSE sec. 26, T. 3 S., R. 45 E.)												
D169437	74-102-1	4.	1.0	0.91	0.20	0.28	0.093	0.052	1.7	0.01L	14.L	40.L
D169438	74-102-2	4.7	.59	.91	.22	.27	.11	.065	.98	.01L	25.	30.L
D169439	74-102-3	5.	.78	1.2	.26	.28	.11	.11	1.5	.01L	38.	41.L
D169440	74-102-4	4.4	.68	.99	.19	.24	.13	.076	1.2	.01L	19.	33.L
D169441	74-102-5	5.	.92	1.0	.15	.21	.11	.055	1.3	.01L	13.L	37.L
D169442	74-102-6	5.	.98	1.1	.14	.21	.11	.044	1.4	.01L	13.L	38.L
D169443	74-102-7	5.	.55	.96	.13	.19	.13	.036	.76	.01L	9.L	26.L
D169444	74-102-8	5.	.64	1.0	.13	.19	.11	.021	1.4	.01L	12.L	34.L
D169445	74-102-9	5.	.97	1.2	.20	.22	.13	.075	2.1	.01L	17.	47.L
D169446	74-102-10	5.	.55	1.4	.19	.18	.11	.033	1.5	.01L	41.	39.L
D169447	74-102-11	5.	.81	.91	.15	.18	.12	.034	2.8	.01L	17.L	49.L
Flowers-Goodale bed, BurRec DH 74-101												
D169475	74-101-14	4.5	1.1	0.90	0.20	0.13	0.28	0.011	1.5	0.01L	26.	37.L
D169476	74-101-15	5.2	.78	.76	.21	.10	.28	.018	1.0	.01L	22.	30.L
Flowers-Goodale bed, BurRec DH 74-102												
D169723	74-102-12	5.	1.4	0.75	0.34	0.13	0.30	0.099	2.2	0.01L	26.	48.L
D169724	74-102-13	5.	.58	.83	.19	.12	.30	.018	.78	.01L	31.	27.L

Table 9

SAMPLE	Ti %	As PPM	Cd PPM	Cu PPM	F PPM	Hg PPM	Li PPM	Pb PPM	Sb PPM	Se PPM
Knoblock bed, BurRec DH 74-101 (NESW sec. 34, T. 3 S., R. 45 E.)										
D169028	0.043	3.	0.1L	9.4	70.	0.12	9.6	9.4	2.3	.3
D169029	.040	1.	.1L	7.7	80.	.02	13.4	11.6	.2	.2
D169030	.014	1.	.1L	3.2	40.	.01	4.1	3.1	.1	.2
D169031	.022	2.	.1L	4.3	50.	.03	4.2	3.9	.2	.2
D169032	.022	1.	.1L	4.7	45.	.01	4.8	5.5	.2	.2
D169033	.047	1.	.1L	9.7	45.	.02	9.7	5.9	.3	.1
D169034	.047	12.	.1L	7.0	35.	.01	10.3	5.3	.5	.3
D169035	.013	1.	.1L	3.4	35.	.01	2.4	4.5	.1	.4
D169036	.064	1.L	.1L	6.0	30.	.02	6.4	5.0	.2	.4
D169037	.042	1.L	.1L	5.6	30.	.01	7.8	4.7	.3	.3
D169038	.021	1.L	.1L	3.6	25.	.01	4.8	2.6	.1	.2
D169039	.035	1.L	.1L	7.0	25.	.04	4.1	3.5	.2	.3
D169040	.051	2.	.1L	11.8	85.	.06	6.4	4.6	.7	.5
Knoblock bed, BurRec DH 74-102 (NWSE sec. 26, T. 3 S., R. 45 E.)										
D169437	0.039	1.	0.1L	5.3	55.	0.05	10.5	6.4	0.5	0.5
D169438	.018	1.	.1L	3.9	50.	.05	2.5	3.8	.2	.2
D169439	.028	1.	.1L	4.5	65.	.04	3.4	5.2	.3	.6
D169440	.023	1.	.1L	4.3	60.	.06	3.2	35.1	.3	.6
D169441	.046	1.	.1L	5.6	50.	.05	10.0	5.9	.5	.4
D169442	.059	1.	.1L	9.4	70.	.32	10.1	4.3	.5	.9
D169443	.020	1.	.1L	4.1	45.	.06	6.4	3.0	.4	.4
D169444	.040	1.	.1L	7.4	30.	.05	6.6	3.9	.2	.6
D169445	.048	1.	.1L	7.5	50.	.05	9.6	7.0	.3	.5
D169446	.031	1.	.1L	6.5	45.	.05	3.2	3.6	.2	.6
D169447	.080	1.	.1L	11.4	50.	.08	6.7	4.5	.4	1.0
Flowers-Goodale bed, BurRec DH 74-101										
D169475	0.033	2.	0.1L	7.9	25.	0.06	6.2	5.1	0.8	0.6
D169474	.029	2.	.1L	7.1	30.	.05	4.2	2.7	1.0	.7
Flowers-Goodale bed, BurRec DH 74-102										
D169723	0.042	4.	0.1L	10.1	45.	0.11	8.6	4.9	1.4	0.4
D169724	.021	1.	.1L	5.8	40.	.04	2.9	3.5	.4	.2

Table 9

SAMPLE	Th PPM	U PPM	Zn PPM	B PPM-S	Ba PPM-S	Be PPM-S	Co PPM-S	Cr PPM-S	Ce PPM-S	Ge PPM-S
Knoblock bed, BurRec DH 74-101 (NESW sec. 34, T. 3 S., R. 45 E.)										
D169028	3.1	1.2	21.4	50	500	3	2	5	3	10
D169029	4.0	1.3	20.6	50	500	N	.7L	5	5	N
D169030	2.0<	.3	5.7	70	200	.2	.7L	2	1	N
D169031	2.5	.3	10.9	70	200	N	.7L	2	2	N
D169032	1.9	.4	9.8	50	200	N	.7L	2	1.5	N
D169033	2.2	.7	15.0	70	500	N	.7L	5	2	N
D169034	2.3	.7	10.5	70	200	N	.7L	2	2	N
D169035	2.0 <	.1<	11.3	50	300	N	.7L	1.5	.7	N
D169036	3.6	.8	11.9	70	150	N	N	2	1.5	N
D169037	2.9	1.1	5.9	70	150	N	N	2	2	N
D169038	1.9	.4	4.7	70	200	N	N	1.5	1	N
D169039	2.0<	.6	5.5	70	100	N	N	1.5	1.5	N
D169040	2.6	1.2	17.0	100	200	2	1	10	3	N
Knoblock bed, BurRec DH 74-102 (NWSE sec. 26, T. 3 S., R. 45 E.)										
D169437	7.3	1.8	8.9	100	300	0.3	N	3	3	N
D169438	2.3	.2	8.3	70	500	.2	.7L	2	1	N
D169439	2.6	.4	11.5	50	1500	N	.7L	3	2	N
D169440	3.3	.1<	90.2	50	500	N	.7L	3	5	N
D169441	2.4	.7	6.7	70	150	N	.7L	2	2	N
D169442	3.8	1.0	5.8	70	150	N	.7L	2	3	N
D169443	2.1	.3	5.9	70	700	N	.7L	2	2	N
D169444	2.9	.8	5.8	50	500	N	N	2	2	N
D169445	5.3	.9	13.1	70	500	N	N	3	3	N
D169446	2.3	.6	7.3	100	300	N	.7L	3	2	N
D169447	2.0<	1.6	6.4	70	200	N	N	3	3	N
Flowers-Goodele bed, BurRec DH 74-101										
D169475	2.0<	1.5	5.1	100	700	1	0.7L	2	2	N
D169476	3.1	1.0	4.7	100	500	1.5	.7	3	3	N
Flowers-Goodele bed, BurRec DH 74-102										
D169723	4.0	2.6	14.2	70	300	1	1	3	5	N
D169724	1.9	.6	4.2	100	500	.7	.7	1.5	2	N

Table 9 (cont)

Table 9

Sample	La PPM-S	Mo PPM-S	Nb PPM-S	Ni-PPM-S	Sc-PPM-S	Sr-PPM-S	V PPM-S	Y PPM-S	Yb PPM-S	Zr PPM-S
Knoblock bed, BurRec DH 74-101 (NESW sec. 34, T. 3 S., R. 45 E)										
D169028	10	1	5	3	2	200	10	7	0.7	30
D169029	N	1	3	2	1.5	200	10	3	.5	20
D169030	5	.5	2 L	1	1	300	5	2	.2	10
D169031	5	.5	2 L	1	.7	200	5	1.5	.2	10
D169032	N	5	2 L	1	.7	200	5	1.5	.1	10
D169033	N	.7	2 L	1	1	500	7	1.5L	.1L	15
D169034	N	.5	2 L	1	.7	300	5	1.5L	.1L	10
D169035	N	.5	2 L	1	.7L	300	3	1	.1	5
D169036	N	1	2	1L	N	200	2	2	.2	30
D169037	N	.5L	1.5	1L	.7	200	5	1.5	.2	15
D169038	5	.7	2 L	1	.7	300	3	1.5	.1	10
D169039	5	.5L	2 L	1	.7L	200	3	1.5L	.1	10
D169040	10	.7	2	2	2	200	20	3	.5	20
Knoblock bed, BurRec DH 74-102 (NWSE sec. 26; T. 3 S., R. 45 E)										
D169437	7	0.7	2	1	1	300	5	2	0.2	20
D169438	5	.5	N	1	.7	300	3	2	.1	10
D169439	7	.7	N	1	1	500	7	2	.2	15
D169440	5	5	2 L	1	1	500	5	1.5	.2	10
D169441	7	.5L	2 L	1	1.5	500	7	1.5	.2	15
D169442	7	.5L	2 L	1	1.5	200	7	1.5	.2	15
D169443	5	.5	2 L	1	.7	500	5	1	.1	10
D169444	5	N	2 L	1	1	500	7	1.5	.2	15
D169445	N	.5L	2 L	1L	1	300	7	2	.2	20
D169446	N	.7	N	1L	1	700	7	2	.2	15
D169447	N	N	2	1	1	300	7	2	.2	30
Flowers-Goodale bed, BurRec DH 74-101										
D169475	7	0.7	2 L	1	1.5	500	7	5	0.5	15
D169476	5	1	1.5	1	2	300	7	3	.3	15
Flowers-Goodale bed, BurRec DH 74-102										
D169723	N	1.5	2 L	2	2	300	10	3	0.3	20
D169724	5	.5	2 L	1	1	500	3	2	.2	10

Table 10.--Major and minor oxide and trace element composition of thirty-nine core samples of rocks above and below the Knoblock coal bed from Otter Creek area, Powder River County, Montana. Values are in either percent or parts per million. L after a value means less than the value shown, N means not detected, and B means not determined. S after the element title means that the value listed was determined by semiquantitative spectrographic analysis. The spectrographic results are to be identified with geometric brackets whose boundaries are 1.2, 0.83, 0.56, 0.38, 0.26, 0.18, 0.12, 35c., but are reported arbitrarily as mid-points of those brackets, 1.0, 0.7, 0.5, 0.3, 0.2, 0.15, 0.1, etc. The precision of the spectrographic data is approximately one bracket at 68 percent, or two brackets at 95 percent confidence.

SAMPLE	Field No.	(ft)	ASH %	Al_2O_3 %	CaO %	Fe_2O_3 %	MgO %	Na_2O %	K_2O %	SO_3 %	SiO_2 %	Cl %
D169726	74-101-A	0.5 - 5.6	97.7	13.	8.0	4.3	3.6	1.0	2.5	.20	60.	.10L
D169727	74-101-B	5.6 - 14.4	98.3	12.	8.7	2.8	3.1	1.0	2.2	.13	59.	.10L
D169728	74-101-C	14.4 - 30.9	95.4	18.	6.6	4.6	3.7	.72	2.4	.90	58.	.10L
D169729	74-101-D	30.9 - 41.9	96.2	18.	4.1	4.1	2.8	.57	2.8	1.0	59.	.10L
D169730	74-101-E	41.9 - 74.0	92.0	19.	2.6	3.8	2.1	.90	2.7	.90	63.	.10L
D169731	74-101-F	74.0 - 116.2	98.6	14.	2.2	2.0	1.6	1.3	2.3	.11	72.	.10L
D169732	74-101-G	119.9 - 133.2	98.7	14.	6.7	3.5	3.8	.99	2.7	.10L	59.	.10L
D169733	74-101-H	135.2 - 164.6	99.9	10.	8.2	2.1	4.0	.86	1.8	.10L	62.	.10L
D169734	74-101-I	164.6 - 168	97.4	11.	9.6	5.0	4.2	.89	2.0	.10L	64.	.10L
D169735	74-101-J	168 - 198.4	99.0	18.	7.0	4.2	4.1	.56	3.2	.10L	62.	.10L
D169751	74-101-K	239.4 - 260.2	95.8	20.	.36	3.1	1.6	.34	3.8	.18	68.	.10L
D169752	74-101-L	260.2 - 284.5	97.0	14.	4.4	3.9	3.5	.65	2.4	.10L	70.	.10L
D169753	74-101-M	286.7 - 298.7	97.4	15.	13.	6.3	4.8	.53	2.8	.10	49.	.10L
D169754	74-101-N	299.7 - 302.0	96.3	17.	9.9	3.1	4.4	.49	3.0	.10L	55.	.10L
D169755	74-101-O	302.0 - 312.2	95.7	17.	7.3	4.5	3.8	.65	3.1	.25	60.	.10L
D169756	74-101-P	313.2 - 358.2	97.3	12.	7.8	2.7	3.8	.80	2.1	.10L	68.	.10L
D169757	74-101-Q	361.3 - 372.8	99.1	13.	7.4	2.8	3.6	1.8	2.1	.10L	67.	.10L
D169758	74-101-R	385.4 - 401.5	99.0	11.	5.0	2.0	2.9	1.9	2.0	.16	71.	.10L
D169759	74-101-S	401.5 - 407.5	96.3	14.	10.	5.1	5.2	.80	2.8	.10L	50.	.10L
D169736	74-102-A	0 - 3.5	99.7	8.8	13.	2.9	5.9	.62	1.6	.10L	56.	.10L
D169737	74-102-B	3.5 - 16	96.8	17.	7.1	4.6	3.7	.72	3.1	.10L	65.	.10L
D169738	74-102-C	16 - 17.2	98.4	13.	7.1	1.8	3.4	.86	2.2	.10L	74.	.10L
D169739	74-102-D	17.2 - 23.7	94.9	19.	5.0	0.9	3.6	.58	3.6	.10L	60.	.10L
D169740	74-102-E	23.7 - 88.7	100.0	11.	8.0	2.2	3.8	.88	2.1	.10L	70.	.10L
D169741	74-102-F	88.7 - 110.7	97.1	16.	8.4	3.4	3.9	.80	2.7	.10L	65.	.10L
D169742	74-102-G	110.7 - 126.1	97.3	15.	5.0	3.7	4.0	.69	2.8	.10L	63.	.10L
D169743	74-102-H	185.2 - 192.4	98.2	18.	4.1	3.7	3.7	.40	3.2	.15	60.	.10L
D169744	74-102-I	192.4 - 196.7	97.8	13.	8.0	3.3	2.5	.58	2.2	.10L	59.	.10L
D169745	74-102-J	201.1 - 204.2	97.7	17.	5.2	2.7	3.9	.61	2.8	.47	60.	.10L
D169746	74-102-K	204.2 - 212.9	98.2	11.	7.7	1.9	4.0	.67	2.0	.13	63.	.10L
D169747	74-102-L	212.9 - 234.7	95.7	18.	8.3	4.4	4.0	.57	3.3	.90	52.	.10L
D169748	74-102-M	234.7 - 289.2	97.5	12.	9.3	3.1	4.5	.76	2.2	.10L	57.	.10L
D169749	74-102-N	299.7 - 329.7	98.1	12.	8.2	2.5	4.5	.80	2.1	.10L	61.	.10L
D169750	74-102-O	329.3 - 334.2	95.4	17.	8.5	7.2	4.3	.69	2.8	.10L	55.	.10L

Table 10

SAMPLE	MnO %	P_2O_5 %	TiO_2 %	Cd PPM	Cu PPM	Li PPM	Pb PPM	Zn PPM	B PPM-S	Ba PPM-S
D169726	0.083	0.10L	0.51	1.L	26.	30.	25.L	64.	70	700
D169727	.048	.10L	.43	1.L	18.	26.	25.L	50.	50	500
D169728	.084	.10L	.57	1.L	36.	46.	25.L	94.	70	700
D169729	.058	.10L	.57	1.L	32.	46.	25.L	100.	70	1000
D169730	.050	.10L	.64	1.L	36.	42.	25.	114.	50	700
D169731	.027	.10L	.39	1.L	14.	20.	25.L	62.	50 L	1500
D169732	.048	.10L	.50	1.L	26.	30.	25.	60.	50	300
D169733	.029	.10L	.43	1.L	10.L	18.	25.L	40.	70	200
D169734	.060	.10L	.34	1.L	16.	42.	25.L	51.	50	300
D169735	.074	.10L	.47	1.L	28.	40.	25.L	82.	70	500
D169751	.024	.18	.69	1.L	38.	42.	25.L	94.	70	700
D169752	.048	.10L	.48	1.L	19.	28.	25.L	56.	50	500
D169753	.064	.10L	.49	1.L	26.	32.	25.	82.	70	500
D169754	.064	.10L	.55	1.L	30.	32.	25.L	88.	70	700
D169755	.068	.10L	.56	1.L	29.	32.	25.L	88.	70	500
D169756	.034	.10L	.45	1.L	14.	22.	25.L	50.	50	500
D169757	.041	.10L	.46	1.L	19.	28.	25.L	58.	50	500
D169758	.020L	.10L	.38	1.L	10.L	22.	25.L	44.	50	300
D169759	.090	.10L	.48	1.L	30.	32.	25.L	78.	70	500
D169736	.045	.10L	.27	1.L	10.L	16.	25.L	38.	50 L	300
D169737	.071	.10L	.47	1.L	24.	34.	25.L	76.	70	500
D169738	.024	.10L	.41	1.L	18.	24.	25.L	62.	50	300
D169739	.13	.10L	.47	1.L	26.	44.	25.L	88.	70	700
D169740	.029	.10L	.40	1.L	10.L	22.	25.L	48.	50	300
D169741	.068	.10L	.46	1.L	24.	30.	25.L	70.	70	500
D169742	.054	.10L	.52	1.L	30.	30.	25.L	70.	70	500
D169743	.046	.10L	.57	1.L	24.	32.	25.L	80.	70	500
D169744	.054	.10L	.46	1.L	26.	20.	25.L	60.	50	300
D169745	.020L	.10L	.52	1.L	28.	30.	25.L	140.	50	500
D169746	.022	.10L	.37	1.L	10.L	20.	25.L	48.	50	300
D169747	.083	.10L	.52	1.L	30.	36.	25.L	86.	70	500
D169748	.048	.10L	.44	1.L	20.	24.	25.L	50.	50	500
D169749	.040	.10L	.45	1.L	24.	24.	25.L	58.	50	500
D169750	.16	.10L	.51	1.L	26.	32.	25.L	82.	50	700

Table 10

SAMPLE	Be PPM-S	Co PPM-S	Cr PPM-S	Ga PPm-S	Ge PPM-S	La PPM-S	Mo PPM-S	Nb PPM-S	Ni PPM-S	Sc PPM-S	Sr PPM-S
D169726	N	10	50	15	N	70	N	20 L	15	10	200
D169727	N	7 L	30	15	N	70	N	20 L	10	10 L	200
D169728	N	15	50	20	N	70	N	20 L	30	10	150
D169729	N	15	70	20	N	70	7 L	20 L	30	15	300
D169730	N	15	70	20	N	70	7 L	20 L	30	15	200
D169731	N	10	70	15	N	70	N	20 L	20	10 L	200
D169732	N	7 L	30	15	N	70 L	N	N	15	10 L	70
D169733	N	N	20	10	N	70 L	N	N	10	N	70
D169734	N	10	30	10	N	N	N	N	15	N	100
D169735	N	10	50	15	N	N	N	N	15	10	70
D169751	2 L	7 L	70	20	N	70	N	20 L	10	15	70
D169752	N	7 L	30	10	N	N	N	20 L	15	10	50
D169753	N	7 L	50	15	N	N	N	N	15	10	150
D169754	N	10	70	20	N	70 L	N	N	15	10	150
D169755	N	7 L	50	15	N	70 L	N	N	10	10 L	100
D169756	N	7 L	50	10	N	N	N	N	10 L	N	100
D169757	N	7 L	30	10	N	N	N	N	10	N	100
D169758	N	N	20	10	N	N	N	N	10 L	N	30
D169759	N	7 L	50	15	N	N	N	N	10	10 L	150
D169736	N	N	20	10	N	N	N	N	10 L	N	150
D169737	N	7 L	50	20	N	N	N	N	15	10	100
D169738	N	7 L	20	10	N	70 L	N	N	10 L	N	70
D169739	2 L	10	50	20	N	70 L	N	20 L	20	15	100
D169740	N	N	20	10	N	N	N	N	10 L	N	70
D169741	N	10	30	15	N	N	N	N	15	10	100
D169742	N	10	50	15	N	N	N	20 L	15	10	70
D169743	N	7 L	50	15	N	N	N	20 L	15	10	70
D169744	N	7 L	30	15	N	N	N	N	10	N	70
D169745	N	15	70	20	N	N	7	N	30	10 L	100
D169746	N	7 L	30	10	N	N	N	N	10	N	70
D169747	N	10	70	15	N	N	N	N	15	10	150
D169748	N	7 L	50	15	N	N	N	N	10	10 L	150
D169749	N	7 L	30	10	N	N	N	N	10	10 L	100
D169750	N	7 L	50	15	N	N	N	N	15	10	150

Table 10

SAMPLE	V PPM-S	Y PPM-S	Yb PPM-S	Zr PPM-S	As PPM	F PPM	Hg PPM	Sb PPM	Se PPM	Th PPM
D169726	70	30	3	150	5.	710.	0.02	1.1	.1	9.2
D169727	70	20	2	150	4.	570.	.24	1.0	.1L	7.5
D169728	100	30	3	150	8.	935.	.03	1.6	.2	12.0
D169729	150	20	3	150	12.	785.	.05	1.6	.3	12.2
D169730	150	30	3	200	12.	710.	.07	1.4	.2	9.9
D169731	70	20 L	2	150	10.	495.	.02	.5	.1L	6.7
D169732	70	20	2	150	5.	815.	.02	1.6	.1L	9.5
D169733	50	20 L	2	100	5.	480.	.03	1.0	.1L	8.0
D169734	70	20	3	150	5.	540.	.03	1.4	.1L	8.3
D169735	70	30	3	150	12.	825.	.05	2.3	.1L	11.5
D169751	70	20	3	150	8.	1010.	.12	1.2	.9	14.1
D169752	80	20 L	2	150	5.	584.	.06	1.0	.4	7.7
D169753	70	20	2	100	12.	736.	.09	1.6	.1L	9.2
D169754	70	20	2	100	12.	770.	.07	1.7	.1L	10.7
D169755	70	20	2	100	20.	855.	.08	1.9	.1	12.4
D169756	50	20 L	2	200	4.	560.	.04	1.0	.1L	7.9
D169757	50	20 L	2	200	5.	530.	.05	1.0	.1L	7.6
D169758	30	20 L	2 L	150	8.	450.	.05	1.0	.1L	7.6
D169759	50	20 L	2 L	100	5.	825.	.05	1.3	.1L	10.1
D169736	30	20 L	2 L	100	4.	495.	.02	.9	.1L	6.0
D169737	70	30	3	150	8.	830.	.03	1.6	.1L	10.3
D169738	30	20	3	150	5.	525.	.02	1.3	.1L	9.4
D169739	100	30	3	100	25.	935.	.05	1.8	.1	10.3
D169740	30	20 L	2 L	150	8.	500.	.02	1.0	.1L	9.1
D169741	70	30	3	150	8.	695.	.05	1.7	.1L	11.8
D169742	70	20	3	150	5.	720.	.07	1.4	.2	10.8
D169743	70	20	3	100	20.	880.	.08	1.7	.2	10.7
D169744	50	20	2	100	5.	585.	.05	1.1	.1	9.1
D169745	70	30	3	150	20.	760.	.17	2.2	.3	10.8
D169746	50	20	3	150	10.	435.	.08	.9	.1L	7.8
D169747	70	20	3	70	30.	920.	.13	3.0	.3	8.6
D169748	70	20 L	2	100	5.	535.	.05	1.1	.1L	9.2
D169749	30	20 L	2	150	5.	520.	.05	1.2	.1L	9.2
D169750	70	20	3	100	8.	772.	.07	1.2	.1L	11.7

Table 10

SAMPLE	U PPM	TOTAL C%	ORGNC C%	CRBNT C%	TOTAL S%
D169726	4.4	2.37	.10L	2.37	0.11
D169727	3.2	2.52	.10L	2.52	.03
D169728	3.8	1.85	.20	1.65	.33
D169729	4.1	2.68	1.40	1.28	.47
D169730	4.5	2.85	2.00	.85	.37
D169731	2.1	.90	.20	.70	.02
D169732	3.5	2.56	.10	2.45	.02
D169733	2.9	2.72	.10L	2.72	.01L
D169734	3.4	3.08	.10L	3.08	.01
D169735	3.6	2.78	.30	2.48	.04
D169751	4.6	.54	.40	.11	.02
D169752	3.3	2.15	.20	1.95	.05
D169753	3.4	4.21	.10L	4.14	.11
D169754	3.2	3.34	.10L	3.32	.06
D169755	3.6	3.20	.70	2.50	.12
D169756	2.9	2.70	.10L	2.67	.02
D169757	3.1	2.66	.10L	2.59	.01L
D169758	2.4	1.76	.10L	1.76	.09
D169759	3.4	3.75	.10L	3.75	.03
D169736	2.4	4.53	.10L	4.53	.01L
D169737	3.5	2.40	.10L	2.35	.01L
D169738	3.1	2.19	.10	2.07	.01L
D169739	3.7	2.79	.50	2.29	.05
D169740	3.3	2.64	.10L	2.60	.01
D169741	3.3	2.95	.30	2.65	.03
D169742	3.8	2.38	.30	2.08	.03
D169743	3.6	2.68	.90	1.78	.06
D169744	3.0	3.16	.20	2.96	.03
D169745	7.4	2.94	1.00	1.94	.41
D169746	2.8	2.95	.30	2.95	.14
D169747	4.0	4.69	2.00	2.64	.42
D169748	3.1	3.33	.10L	3.33	.02
D169749	3.5	3.00	.10L	2.99	.03
D169750	3.1	3.46	.10	3.33	.04

Table 10 (Cont)

Table 11.--Comparison of composition of Knoblock with composition of subbituminous coals of the Northern Great Plains

	Knoblock coal (24 samples)	NGP subbituminous coals (67 samples) 1/
Btu	8,110	9,000
	in percent	
Moisture (as rec'd	30	20
Fixed carbon (as rec'd)	35	38
Oxygen (as rec'd)	39	30
SiO_2 (in ash)	38	25
Na_2O " "	4	0.5
CaO " "	16	15
MgO " "	4	4
	in parts per million	
As (whole coal)	2	2
B " "	70	50
Ba " "	300	200
Hg " "	0.05	0.08
Pb " "	6.4	6
Se " "	0.4	0.8 (51 samples)
U " "	0.8	0.7
Zn " "	13	7

1/ Swanson, V. E., Huffman, Claude, Jr., and Hamilton, J. C., 1974, Composition and trace-element content of coal, Northern Great Plains area: Contribution to Mineral Resources Work Group, Northern Great Plains Resources Program

Table 12 shows the range of and average elemental content on the whole-coal basis, of those constituents commonly regarded as being of importance from the standpoint of coal utilization. Some of the elements, such as mercury and arsenic, are of interest because of the environmental problems that might occur if they are present in inordinate amounts; others such as thorium and uranium are of interest because they could be recovered from coal ash if they are present in sufficiently large quantities. Based on the average 5.5 percent ash content of the Knoblock coal, trace elements such as thorium and uranium will be enriched in the ash approximately 18 times their whole-coal average.

The average concentration of trace elements in the Knoblock coalbed in the Otter Creek area is shown in table 12. Generally this concentration is less than the average for these elements in the continental crust (Taylor, 1964). Only selenium, 0.4 ppm for the Knoblock compared to 0.05 ppm for the crustal average, is higher. Even this amount is relatively low.

Table 12.--Elements that can affect potential utilization of coals--content in 24 samples from Otter Creek area in parts per million

	Concentration in Knoblock bed		Average, Continental crust (Taylor, 1964) 1/
Element	Range	Average	
As	1 - 12	2	1.8
Cd	0.1 - .1	.1	.2
Cu	3.2 - 12	6.4	55
F	25 - 85	48	625
Hg	0.01 - .32	0.5	.08
Li	2.5 - 13	6.7	20
Pb	2.6 - 35	6.4	12.5
Sb	0.1 - 0.7	.4	.2
Se	0.1 - 1.0	.4	.05
Th	2.0 - 7.3	3.0	9.6
U	0.1 - 1.6	.8	2.7
Zn	4.7 - 90	13	70

1/ Taylor, S. R., 1964, Abundance of chemical elements in the continental crust: A new table: Geochim. et Cosmochim. Acta, v. 28, no. 8, p.1273-1285

SOIL

General Description

In the detailed soil inventory of the Otter Creek Study site, ten soil series were delineated to identify their potential for use in reconstructed soil profiles in surface coal mine reclamation. In addition, the soil mapping units described include texture, slope and erosion phases.

The ten series are evenly divided between the orders of Aridisols and Entisols, but the areal distribution of the Entisols is much greater. The ten soil series are characterized with respect to their use for surface-mined reclamation as follows:

Series 9001--A fine-loamy, calcareous, mesic, Ustic Torrifluvents. This deep soil has few limitations on its use in a reconstructed profile. Good infiltration, and moisture retention coupled with low salinity make it a productive soil. The limitations are: slight erosiveness by wind and water, low fertility, and high lime zones which may affect soil structure if used on the surface. Depth to shale ranges from 10 to more than 20 feet.

Series 9002--Fine-montmorillonitic to medium-loamy, mesic, Ustollic Haplargids. This moderately deep soil is productive and well suited for use in reclamation work. Moderate to good infiltration, low salinity, high moisture retention, and moderate fertility level are its best features. Soil with moderate infiltration can increase the erosion hazard by reducing moisture intake if used on the surface where slopes are over 7 percent. Depth to shale ranges from 30 inches to more than 60 inches.

Series 9003--A medium-fine-loamy to fine-loamy, calcareous, mesic, Ustic Torriorthents. This shallow soil has many limitations for use in reclamation work. The surface soil is usually nonsaline and nonalkaline on smooth and gently rolling slopes where a "typical" profile may be found. Good moisture retention and moderate fertility level are its best characteristics. The surface material in this soil is extremely variable ranging from 10-12 inches of nonsaline, nonalkaline surface soil to saline clays and saline-alkali fine-loamy material. Lack of depth, and saline and/or alkali material limits its effective use. These soils are usually on moderate to severe slopes and this physical limitation on stripping and stockpiling precludes their use on many locations. The depth to shale ranges from the surface to about 14 inches. Here the underlying geologic material ranges from clay to siltstone which may be saline-alkali or nonsaline, and nonalkaline. The underlying coarse siltstone and fine sandstone are best for reclamation use. Some clayey shale beds can be used effectively below 18 inches in reconstructed profiles.

Series 9004--A fine-loamy, mixed, mesic, Ustollic Camborthids. This soil has few limitations for reclamation use. It has good infiltration and moisture retention, low salinity, and moderate fertility. Significant limitation are zones of high lime concentrations and slight erosiveness. Depth to shale ranges from 8 to more than 12 feet.

Series 9005--A medium-loamy, calcareous, shallow, frigid, Borollic Torriorthents. They are generally well suited for use in reclamation. Good infiltration and moisture retention and low salinity are the desirable characteristics of this soil. Minor limitations are wind erosion hazard and moderately low fertility. Depth to geologic strata is the principal limitation. Depth to shale ranges from 25 to more than 60 inches. The soils located on tabular divides are shallow to silty shale and masses of indurated, lenticular sandstone are common. The highly weathered shale underlying the divides is often nonsaline and nonalkaline. On the moderate to gentle slopes the soil is deeper but the underlying materials is fine loamy to clayey shale. The type and quality of the geologic material is quite diverse and its characteristic texture, salinity, sodicity should not be projected to large or distant areas with similar surface soils.

Series 9006--A medium loamy, calcareous, mesic, Ustic Torrifluvents. This deep soil is often highly saline in the lower solum and alluvial parent material. The upper solum has few limitations on its use in reclamation profile. The lower solum if placed properly in a reconstructed profile can also contribute significantly. The better characteristics of this material are good infiltration and moisture retention. Salinity of the lower solum and alluvial parent material below 2-3 feet will limit use of this material. It is very permeable and will not be toxic of placed below 24 inches. Depth to shale ranges from 5 to over 10 feet.

Series 9007--A fine loamy montmorillonitic Borollic Natrargids. They have fair to poor utility for use in reclamation of coal-mined area. Locally these solenetzic soils are in an intermediate stage of change. In favorable locations, on tabular divides and smooth gentle slopes the sodium has leached downward to about 24 to 30 inches and the upper solum is of fair to good quality. These soils are moderately permeable, low in salinity and sodium, and retain moisture well. The physical conditions of the B horizon is fair to poor. Use of material from tracts with more than 30 percent slick spots should be avoided. Depth to shale and/or sodic siltstone is from 6 to more than 36 inches.

Series 9008--A mixed loamy shallow, calcareous, mesic, Ustic Torriorthents. The soils material has no limitations for use in reclamation of surface-mined area. Best characteristics are moderate fertility, good infiltration and moisture retention. Reconstructed profiles using this soil on the surface will be productive. This soil overlies major areas of baked rock and it may not be mined. It is also quite shallow, and ranges 6 to 24 inches to the baked rock which may be coarse unconsolidated sandstone or hard fine siltstone. The underlying geologic strata is quite sterile and borrowing soil material from from this mapping unit should be avoided if possible.

Series 9009--A medium loamy, calcareous, mesic, Ustollic Torrifluvents. These soils consist of saline alkali, colluvial, and local alluvial material derived from shales. The upper solum is generally well suited for surface-mined reclamation. Its desirable characteristics are good infiltration and moisture retention and low salinity and alkalinity. Limitations include potential erosion hazard by wind and water and low fertility level. The depth of this layer is quite unpredictable except that in the absence of slick spots it is usually no less than 2 feet deep. The lower solum and alluvial/colluvial parent material are usually saline and alkaline. Some of this material may be used in reconstructed profiles but its selection and placement are very important.

Series 9010--A fine montmorillonitic, mesic, Ustollic Haplargids. Reconstructed soil profiles derived from this deep soil will be productive. The most favorable characteristics are good moisture retention and low salinity and alkalinity. Limitations include moderately slow permeability, slight to moderate salinity in the lower solum and colluvial/alluvial parent material. Depth to shale ranges from 4 to more than 10 feet.

Detailed descriptions of the ten soil series are shown on plates 20 through 24. Evaluations of other soil use capability are shown in Appendix A.

Methods

Field mapping was done on aerial photographs at a scale of 1 inch equals 400 feet. Topographic drawings at a scale of 1 inch equals 1,000 feet with 20 foot contour intervals were used for reference when classifying the land. Abney hand levels were used to supplement the topographic drawings.

Representative soil boring sites were selected, and the profiles examined and evaluated in most sizable areas. Additional nontypical profiles were recorded in the heterogeneous soil areas to show the variation within the mapping unit. This information was supplemented by nonrecorded profile examinations as required. Nonrecorded profiles are often located in transitional tracts because soil boundaries can be more accurately determined. In this investigation depth to and quality of shale substrata is very important and many of these profiles were used to determine these characteristics.

The 0 to 16 inch part of the soil profile was exposed with a tile spade, and the physical properties of the soil were evaluated. Particular attention was given to soil structure, consistence and texture. Observable indications of salinity and alkalinity, the color of the soil, and root penetration were recorded.

Effervescence with dilute hydrochloric acid was also checked. Soil profiles selected for possible testing in the greenhouse study were excavated to 36 or more inches with a tile spade and below this with a hand auger to 10 feet. Below 16 or 36 inches the soil profile was exposed for examination and sampling with a hand auger or a mechanical core machine. Using this basic soil information the interrelated effect of the soil, topography, and drainage on the potential of the tract for use in surface-mined reclamation was determined. When the field evaluation is completed, preliminary land class boundaries and symbols were put on aerial photographs.

Systematic traverses were not used in this land classification survey. Instead representative profiles of most soil types were evaluated. Specific soil conditions were covered better by this method. Most soil profiles were examined to 5 feet. Numerous 10-foot borings or to gravel or hard shale were made to check the characteristics of the overburden below the solum.

A soil laboratory was used extensively in connection with the land classification survey and screening tests were performed on all soil samples. These tests included pH, settling volume, disturbed hydraulic conductivity, and soluble salts of a 1 to 5 soil water suspension. More detailed soil analyses were made as needed. Tests and analyses listed below were made on each horizon of the master sites.

Soil samples from natural horizons and layers were tested in the laboratory. Tests in the following list were performed on soil samples as needed for proper evaluation. The results are shown on plates 25 and 26.

PSA - The procedure is a modification of the pipette method. The soil is not treated with hydrogen peroxide for destruction of organic matter, and is not washed for removal of salts (Kilmer and Alexander, 1949).

Moisture retention - Porous plates are used for moisture retention measurement of soils at all pressures (Richards, 1947 and 1949b and Richards and Weaver, 1944).

Disturbed hydraulic conductivity - Soils are tamped mechanically. City water is used for the test. The temperature of the water is maintained at about 85 degrees F. (Fireman, 1944).

Settling volume - The soil used for the 1:5 dilution measurements is used for this determination. Distilled water and 10 ml of 30% calcium chloride solution are used (U.S.B.R. Reclamation Instructions, 1967).

pH - Measured with Beckman Expandomatic pH meter.

Saturation extract - Samples are mixed by hand and extract removed with a Baroid filter press. No preservative added.

Calcium and Magnesium - Determined by EDTA titration.

Sodium and Potassium - Determined with Baird-Atomic Model KY3 flame photometer and Perkin-Elmer Model 306 atomic absorption spectrophotometer.

Carbonate, bicarbonate, chloride, and sulfate - All are based on U.S. Geological Survey procedures (Brown and others, 1970).

The carbonate end-point is taken as pH 8.2.

Chloride is determined by the Mohr method.

Sulfate is determined by the Thorin method using Bausch & Lomb spectrophotometer Spectronic 20.

Nitrate - Determined by phenoldisulfonic acid method and Bausch and Lomb spectrophotometer Spectronic 20 (U.S. Salinity Laboratory Staff, 1954).

Exchangeable sodium and potassium - Based on soluble cations in saturation extract and extractable cations extracted with neutral normal ammonium acetate and measured with Baird Atomic Model KY3 flame photometer and Perkin-Elmer Model 306 atomic absorption spectrophotometer (U.S. Salinity Laboratory Staff, 1954).

Same reference as above

Gypsum - The high moisture percentage is a 1:5 dilution (U.S. Salinity Laboratory Staff, 1954).

Gypsum requirement - Difference between Ca concentration of added gypsum solution and Ca+Mg Concentration in filtrate, as meq/liter, times 2 (U.S.Salinity Laboratory Staff, 1954).

Calcium carbonate equivalent - Back titration with 0.4N NaOH to neutralize 0.4N HCl remaining after boiling period. Two drops of phenolphthalien indicator are used (U.S. Salinity Laboratory Staff, 1954).

Organic carbon - The wet-combustion method of Walkley is used, and diphenylamine is the indicator (Walkley, 1947).

Cation Exchange Capacity - Determined by using 1.0N sodium acetate solution at pH 8.2 and 1.0N ammonium acetate at pH 7.0. Sodium determined by Perkin-Elmer Model 306 atomic absorption spectrophotometer.

The field evaluation of the soil quality mapping units was made in accordance with specifications developed for this investigation. These specifications are on table 13. When laboratory analyses and other data became available the field evaluation was reviewed, changed as needed and finalized.

Separable land classification delineations are described on table 14. The soil type and the most important characteristics are contained in the description. Other factors covered are topography, vegetation, and the expected management requirements for reclamation.

Table 13
United States
Department of Interior
Bureau of Reclamation
August 1974

LAND CLASSIFICATION SPECIFICATIONS - SURFACE MINE RECLAMATION
Source of Planting Media Material for Revegetation of Disturbed Areas
BLM/BR Cooperative Program EMRIA
Otter Creek Study Site - Montana

Land Characteristics	Symbols Inform. & Defic.	S 1	S 2	S 3	S 4
SOILS					
Textures		Sandy loams to clay loams.	-Sandy loam to silty clay loams.	Loamy sand to silty clay loam.	Loamy sand to clay.
Very light	v		Sandy loams sufficiently coarse to slightly reduce productivity, moisture retention and may increase erosiveness slightly.	Loamy sand in sufficient quantity to moderately reduce productivity and moisture retention, and may increase erosiveness moderately.	Loamy sand in sufficient quantity to severely reduce productivity and moisture retention, and may increase erosiveness severely.
Heavy	h		Silty clay loams generally should be placed below 12" in reconstructed profile.	Placement of silty clay loams same as S 2.	Clays should be placed in the reconstructed profile at a depth that will not adversely affect revegetation.
Depth					
Soil depth to shale or other geologic strata	b	36" or more of good free-working soil.	18" to 36" of good free-working soil.	10" to 18" of good free-working soil.	0" to 10" of good free-working soil.
Alkalinity and Salinity	a	Sufficient overburden (soil and geologic strata) to produce a 60" profile that has less than 3.0 milliequivalents of exchangeable sodium per 100 grams of soil for cation exchange capacities of less than 25 milliequivalents per 100 grams, or less than 12 percent for exchange capacities of 25 milliequivalents per 100 grams or greater. In the absence of specific field permeability information and complete sodium/exchange capacity analyses the SAR should not exceed 9 in clay textures, the limit ranging with texture to SAR 20 in loamy sands.	Same as Class 1.	Same as Class 1.	Same as Class 1.
		Overburden with characteristics (chemical and physical) capable of producing an expected electrical conductivity at equilibrium with the natural precipitation as follows must be available.	Overburden with characteristics (chemical and physical) capable of producing an expected electrical conductivity at equilibrium with the natural precipitation as follows must be available.	Overburden with characteristics (chemical and physical) capable of producing an expected electrical conductivity at equilibrium with the natural precipitation as follows must be available.	Overburden with characteristics (chemical and physical) capable of producing an expected electrical conductivity at equilibrium with the natural precipitation as follows must be available.
		Depth EC x 10^3 Is available 0-36" < 4.0 readily	Depth EC x 10^3 Is Available 0-24" < 4.0 readily	Depth EC x 10^3 Is available 0-18" < 4.0 readily	Depth EC x 10^3 Is Available 0-10" < 4.0 scarcely
Moisture Retention	q	Overburden material capable of retaining 7 to 8" of available water in 48" of material.	Overburden material capable of retaining 5 to 7" of available water in 48" of material.	Overburden capable of retaining 3.5 to 5" of available water in 48" of material.	Overburden material capable of retaining 3" or more of available water in 48" of material.
Field Infiltration Rate	p	.30"/hr. 0-24" (Average rate of total infiltration in 12 hours) .20"/hr. 24-48" (Saturated flow)	.25"/hr. 0-12" (Average rate of total infiltration in 10 hours) .12"/hr. 12-48" (Saturated flow)	.20"/hr. 0-12" (Average rate of total infiltration in 10 hours) .06"/hr. 12-48" (Saturated flow)	Same as S 3.
TOPOGRAPHY					
Slope	g	Permissible surface gradient 0 to 3%; g_2 - 3 to 7%; g_3 - 7 to 12%.	Permissible surface gradient 0 to 3%; g_2 - 3 to 7%; g_3 - 7 to 12%.	Permissible surface gradient 0 to 3%; g_2 - 3 to 7%; g_3 - 7 to 12%; and g_4 - 12 to 20%.	Permissible slope gradient All slope classes.
Indurated Sandstone					
Stone, Flags and shards	x	Permissible stone in surface soil that may be stockpiled and reused as surface soil .0 to 2.5" - 5% 2.5 to 10" $<$ 5%	Permissible stone in surface soil that may be stockpiled and reused as surface soil 0 to 2.5" - 10% 2.5 to 10" $<$ 10%	Permissible stone in surface soil that may be stockpiled and reused as surface soil 0 to 2.5" - 20% 2.5 to 10" $<$ 10%	Permissible stone in surface soil that may be stockpiled and reused as surface soil 0 to 2.5" - 25% 2.5 to 10" $\leq$ 15%
Massive and lenticular	r	None.	1 to 5% of area.	5 to 20% of area.	More than 20% of area.

GEOLOGIC STRATA

Sufficient free working and nontoxic material to supplement the available soil material for a minimum 3-foot reconstructed profile. This material must meet the alkalinity requirements for sodium listed above. Salinity, expressed as electrical conductivity EC x 10^3, may increase below the primary root zone of native plants used to revegetate the area. Permissible salinity levels must not inhibit or seriously reduce plant growth.

S 6

This symbol with appropriate informative subsymbols is used to delineate mapping units that are generally unsuited for stripping and stockpiling surface material. One or a combination of the following deficiencies in a mapping unit may result in the use of this symbol: (1) insufficient surface soil and geologic strata of suitable quality at or near the surface; (2) adverse surface topography including excessive slopes, severely undulating complex slopes and indurated sandstone ledges; (3) rocklands with large amounts of massive indurated surface sandstone; (4) toxic overburden, soil and/or geologic strata, on or near the surface. Reclamation of lands with these deficiencies will require material from outside the mapping unit or from deep geologic strata.

Table 14 - Description of Land Classes

Soil Quality	Principal Subgroup	Descriptive Characteristics of the Soil	Topography and Vegetation	Management
1	Sl	This delineation consists of deep alluvial and colluvial soils. They are medium textured, permeable and are nonsaline and nonalkaline. Older terraces exhibit moderate profile development. All textures are porous and well drained. Infiltration and deep percolation rate is moderate to high. Silt loam and fine sandy loam are common textured.	Smooth to slightly channelized very gentle slopes. Vegetative cover includes green needle, blue grama, needle-and-thread scattered timothy and smooth brome grasses. Moderate amounts of big and silver sage occur locally.	Entire profile is suitable for surface material, but the higher lime zones should be placed at least 6" below surface.
	Sl_{g2}	Textural classes range from heavy silt loams to fine sandy loams and are similar to Sl soils above. Below 24" the soil effervesces strongly with dilute HCl.	Smooth to slightly complex gentle slopes. Vegetation is similar to Sl.	Same as Sl.
	Sl_{g3}	Sandy loams are the predominant textures in the upper 5'. Lower horizons may be clay loams with slightly restricted water movement. C horizons have moderate to high lime.	Smooth to slightly complex moderate slopes. Side-oats grama and prairie june grass grow in association with the grasses above.	The moderately fine textured layers in the C horizon should be placed below 12".

Table 14 (cont)

Soil Quality	Principal Subgroup	Descriptive Characteristics of the Soil	Topography and Vegetation	Management
2	S2	This delineation consists of deep alluvial soils in narrow valleys of upland drainages, deep to moderately deep colluvial soils and some residual soils. Each soil type has one or more soil limitation. Limitations include one or more of the following: permeable but highly saline lower horizons, clay rich layers, restricted permeability, slight to moderate salinity and alkalinity, limited moisture retention, and shallow to shale with good surface soil.	Very gentle slopes that may be broken by drainage channels. Smooth very gentle foot slopes and tabular divides. Native vegetation consists of western wheat grass, blue grama, needle-and-thread, green needle with other minor grasses and broken stands of silver and big sage.	Selection of overburden material for use on the surface will require moderate review of field data and possibly selective stripping and stockpiling. This level of selection and placement of material is necessary for the most effective use of available overburden. With the above selection and placement, reclamation should not be difficult and average management should be adequate.
	$S2_{g2}$	Salinity and depth of soil over shale are the most common soil limitations. Other characteristics as above occur but to a lesser degree.	Smooth gentle foot slopes are very common in this delineation. Vegetation is similar to S2 with side-oats grama and little bluestem being common in some tracts.	Same as S2.

Soil Quality	Principal Subgroup	Descriptive Characteristics of the Soil	Topography and Vegetation	Management
	$S2_{g3}$	Largely colluvial slopes with a deep to shallow soil mantle over shale. Salinity and salinity with slight alkalinity are common in the lower horizons and colluvial parent material. Shallow shale on upper slopes limits the amount of available soil material.	Intermediate moderate slopes below rounded ridge tops that may be broken by occasional sandstone outcrops. Pine trees are common on the north and east facing slopes and western wheat grass is less common.	If returned to the original gradient wind and water erosion may cause minor management problems. Selection of usable overburden from the geologic strata will be equally important as selection and placement of the soil material in the reconstructed profile.
3	S3	This delineation consists of the following soils: shallow colluvial and residual, deep saline affected alluvial, and saline and/or alkali affected moderately deep residual. Other soil limitations for use in reconstructed profiles are clay and permeability. Depth to saline and/or alkaline shale is the most common deficiency. Some randomly located slick spots are common.	Very gentle slopes near natural drains and on tabular divides. Drainages often separate lower slopes into 2 to 20 acre tracts. Western wheat grass is a major component of the plant association on the fine loamy soils. Other grasses include needle-and-thread, prairie june, side-oats grama and thread leaf sedge.	Good quality soil for use on the surface may be deficient locally and soil or geologic strata must be borrowed. Usually adequate overburden can be found but the cost may be moderately high. Use of clay and/or slightly saline material on or near the surface will require above average management.
	$S3_{g2}$	Depth to shale and salinity are the principal deficiencies. A similar distribution of soil textural groups to those in S3 occur in this mapping category.	Smooth gentle to slightly complex foot slopes typify this soil group. Vegetation is similar to S3.	Same as S3.

Soil Quality	Principal Subgroup	Descriptive Characteristics of the Soil	Topography and Vegetation	Management
	$S3_{g3}$	Slowly permeable fine loamy and clayey shallow soil are often found in this delineation at or near the surface. They are quite common below 6 to 12".	Complex moderately steep slopes. Western wheat grass, prairie june, needle-and-thread, and slender wheat grasses make up most of the vegetative cover.	Material for surface use may be in short supply. A moderate to gentle reconstructed slope could help prevent erosion or additional material may be imported. Either method would reduce erosion and sedimentation problems.
	$S3_{g4}$	Soil characteristics are similar to $S3_{g3}$. Shale exposures and local sandstone outcrops are more common on S and SW slopes. Soil material for surface use is more available than in lower quality groups and is usually thicker on the N/NE facing slopes.	Steep slightly complex to simple slopes are common. Ponderosa pine, side-oats grama, little bluestem, slender wheat and prairie june grasses make up most of the vegetative cover.	Stripping and stockpiling may be unrealistic in the upper slope ranges, but intermediate slopes should be within limits of present methods. Material for surface use though not extensive in quantity is often good quality.
4	$S4_{g2}$	This soil quality grouping consists of very shallow soils over geologic strata. Shale and sandstone outcrops are common. Soil deficiencies include clay, salinity, alkalinity, permeability and local spots of coarse sandy material.	Gentle complex to simple slopes. Rill erosion is common on the more adverse soils. Western wheat, needle-and-thread, blue grama and prairie june grasses are more commonly found.	Selective stripping for surface use is recommended. Placement of the lower quality but usable material below 4 to 6" is important. If original gradient is used for reclamation, basin-type surface manipulation should be considered.

Table 14 (cont)

Soil Quality	Principal Subgroup	Descriptive Characteristics of the Soil	Topography and Vegetation	Management
	$S4_{g3\&4}$	Similar to $S4_{g2}$ but shale exposures become a dominant feature on the upper slopes. The developing soil material is often removed by erosion as it is formed.	These moderate to steep slopes are often complex. Western wheat, prairie june, slender wheat, needle-and-thread are most commonly found here.	Stripping will be difficult because of the soil depth and uneven surface. Plant species should be selected that will produce a strong dense root system rapidly. Water erosion hazard may be severe and above average management will be required if returned to original gradient.
	$S4_{g5\&6}$	Surface material in these delineations consists of weathered geologic strata with occasional spots of shallow soil. The chemical composition of the geologic material determines the quality and usefulness in a reconstructed profile and is quite variable below 4 to 6".	Steep to very steep slopes. These areas are often below ledges of massive sandstone. The sparse vegetative cover includes western wheat, prairie june and slender wheat grasses and scattered pine.	Selection of small tracts within each area suitable for stripping and stockpiling for surface use is important. The presence of ledge forming sandstone coupled with the slope precludes stripping surface material from much of each area.

Soil Quality	Principal Subgroup	Descriptive Characteristics of the Soil	Topography and Vegetation	Management
6	S6	This soil quality group consists of solonetz and saline alkali soils. Slick spots are common.	Very gentle slopes. These areas are often on tabular divides and at the head of natural drains that terminate near rolling divides. Western wheat and needle-and-thread grasses are common.	These soils are quite variable. Between slick spots the soil is beginning to revegetate. The columnar horizon may not be sodic but the physical condition will require better than average management. Placement is important.
	$S6_{g2-4}$	Clayey shale is often exposed on weak ridge divides and other exposures are common. Good quality overburden is scarce at or near the surface. High salinity and alkalinity combined with fine loamy textures make most of the material unsuitable for surface use.	Gentle to moderate slopes broken by steep sided gullies. Salt tolerant sedge on the clays and western wheat grass elsewhere are dominant. Prairie june grass and some greasewood occur locally.	Small tracts within large delineations are suitable for stripping, but the relatively low quality material is often not worth the cost.
	$S6_{g5\&6}$	Very shallow soils and partially weathered geologic material. Other surface conditions include barren shale exposures and sandstone outcrops. The material at or near the surface may also be highly saline and/or alkaline.	Steep and very steep slopes that are often below massive sandstone ledges and other highly eroded areas.	The low quality overburden often should be placed below 3' in the reconstructed profile. Material for use at or near the surface should come from selected geologic strata or from areas with deep surface soil.

Results of Land Classification and Soil Inventory

Plates 27, 28, and 29 show the results of the 1971 Soil Survey of the area. A description of the soil series and soil associations are also shown on these drawings. These data are from the Soil Survey, Powder River area, Montana. The Soil Survey was performed jointly by Soil Scientists of the Soil Conservation Service, Forest Service, and the Bureau of Land Management.

In July of 1974 the Bureau of Reclamation, working under contract for the Bureau of Land Management started a detailed investigation of soil and geologic resources of a specific site in the Otter Creek area. The soil investigation was designed to record the existing soil conditions and to determine the potential of the overburden, soil and geologic strata, for use in surface-mined revegetation and reclamation. Two methods of soil mapping were used to delineate, describe, and record the results of this investigation. The results and a brief description of each method follows:

Land Classification Surveys

This detailed survey delineates five basic soil classes, 1 through 4 and 6. These classes are based on the quality and quantity of the soil material and its potential for use in surface-mined reclamation.

The slope phases delineated in the soil inventory were retained as separable mapping units. The tabulation of the results of this survey combines many of the slope phases as their usefulness in evaluating the reclamation potential dictates. The results of this land classification survey are recorded on plates 30, 31, and 32 which show the location, a tabulation of the laboratory results, and a brief statement evaluating the reclamation potential of each soil horizon or significant layer in each profile. A detailed tabulation separating the mapping units into soil quality and topographic groupings is also on these drawings.

The following summary tabulation records the results of the survey in basic soil quality groups:

	S1		S2		S3		S4		S6		Total
Location	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres
Sec.26-3-45	84	20	49	12	69	16	83	20	135	32	420
Sec.34-3-45	38	8	72	16	81	18	123	28	126	29	440
Sec.2-4-45	128	29	47	11	40	9	118	27	107	24	440
Total	250	19	168	13	190	15	324	25	368	28	1,300

Supporting data include Master site data shown on plate 33 and soil profile descriptions recorded on BLM form 7310-9 in Appendix A.

Soil Inventory

This detailed survey delineates 10 soil series and 37 phases. This survey was performed in connection with a detailed land classification. These data are recorded in plates 34, 35, and 36 which show the location and extent of the various mapping units. Also shown on these plates are the tabulations of the soil series and phases. All soil profiles examined and recorded on BLM Form 7310-9 are in the Appendix A. material. Data from the Master sites are shown on plate 33.

The following tabulation summarizes the amount of land in each mapping unit.

Mapping Units	Sec. 26 T. 3 S., R. 45 E.	Sec. 34 T. 3 S., R. 45 E.	Sec. 2 T. 4 S., R. 45 E.	USDA Series
9001			35.9	Haverson
9002	10.8	31.4	23.3	Thurlow
9003	176.9	317.3	260.1	Midway
9004	14.4	13.8	78.0	McRae
9005	57.8	30.7		Lambeth
9				
9006	12.0	14.5	16.1	Unnamed
9007	46.9	1.5	4.2	Unnamed
9008	4.9	23.3		Unnamed
9009	31.3			Unnamed
9010			18.4	Heldt
Total	355.0	432.5	436.0	

Following the completion of the detailed soil inventory in the above sections mapping units were extended into the adjacent sections. Section 35, T. 3 S., R. 45 E., and Section 3, T. 4 S., R. 45 E., were examined in lesser detail. The results of this survey and the detailed survey are shown on plate 37. A tabulation is also shown.

Alternative Methods of Reclamation

The objective of reclamation of surface-mined areas as defined by Montana State Law is to return the mined lands to approximately their natural state. Reclamation shall be accomplished by revegetating with principally native plants on slopes with similar gradients to present conditions, but not exceeding 20 percent. Toxic material encountered must be placed 8 feet below the surface.

Within these constraints three alternate methods of reclamation are considered:

Method 1. - Reclaim mined areas using a similar distribution of shallow and deep soils as found in the natural state.

Method 2. - Reclaim mined areas using a uniform depth of the available high quality overburden, within economic limits, throughout the reclaimed area.

Method 3. - Reclaim mined areas by reconstructing quality profiles in areas of equivalent size and agricultural development potential for dry farming, irrigation as now exists. Small tracts of high quality deep soils may be consolidated to enhance the agricultural potential of the reclaimed area.

Three types of land areas, resulting from the interrelated effect of soil, topography, and drainage, are common in the Otter Creek study site. Some tracts of land are suited only for range and wildlife. The soil is shallow with many shale exposures, and sandstone bluffs are common. Another land type consists of shallow and deep soils. The deep soils have good potential for dry farming except for the size of the tracts. The third type of land area consists of sizeable tracts of deep, high quality soils with surrounding and interspersed shallow to moderately deep soils.

The SW-1/4 of Section 34, T. 3 S., R. 45 E. would most likely be reclaimed by Method 1. Small tracts, with deep overburden of good quality are interspersed in large tracts with shallow overburden. The potential yield of good quality overburden (soil and geologic strata) near the surface is inadequate to appreciably change the overall depth of good material in the reconstructed profile. A more logical source of additional material would be from the deeper geologic strata. In this area the zones from 0 to 14 feet and 140 to 166 feet in Drill Hole 74-101 are available for use. Mimimal stockpiling of overburden will be required. The best use of the available good quality overburden would be to strip and spread it on prepared slopes in a single operation.

The reclaimed area would be best suited for range and wildlife. At other locations with different ownership patterns, similar areas would have considerable utility for recreation. However, the soil-plant association would be improved only slightly from the present conditions and controlled usage by livestock will be necessary for several years after return to private management.

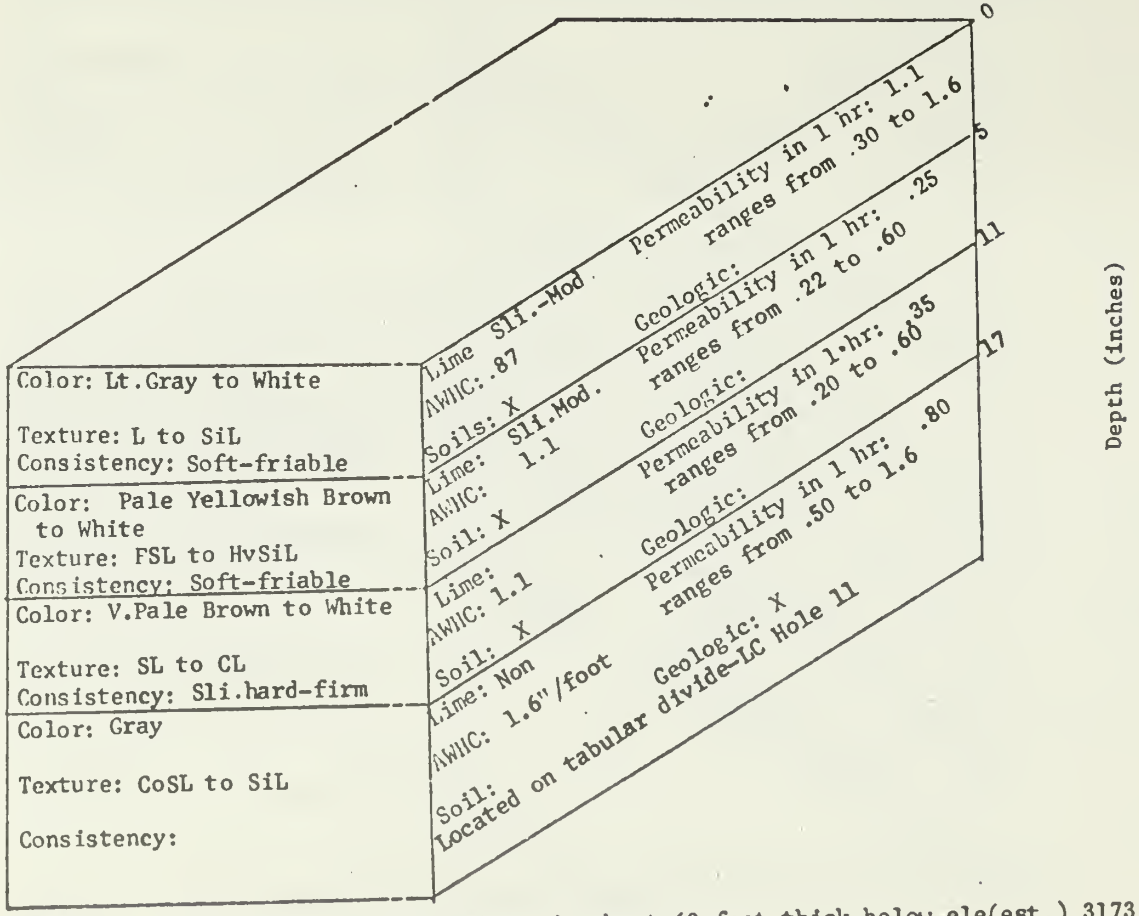
A generalized reconstructed profile for this area is shown on figure 5.

The SW-1/4 of Section 26 and the NE-1/4 Section 34, T. 3 S., R. 45 E. are well suited to reclamation by Method 2. The tracts with deep, high quality overburden are randomly interspersed throughout these quarter sections. The shallow geologic strata here is in places quite adverse so it is very important to use the available surface over-

Generalized Reconstructed Profile NE$\frac{1}{4}$ Sec. 26, T. 3 S., R. 45 E.

pH 1-5	pH $CaCl_2$	EC X 10^3
8.4 (8.1-8.5)	7.7 (7.5-7.8)	< 2.0
8.4 (8.1-9.2)	7.9 (7.6-8.3)	< 2.0 to 4.0
8.6 (8.5-8.8)	8.0 (7.8-8.2)	< 2.0 to 8.0
8.5 (8.3-9.1*)	8.0 (7.8-8.0)	< 2.0

*SAR 2.9



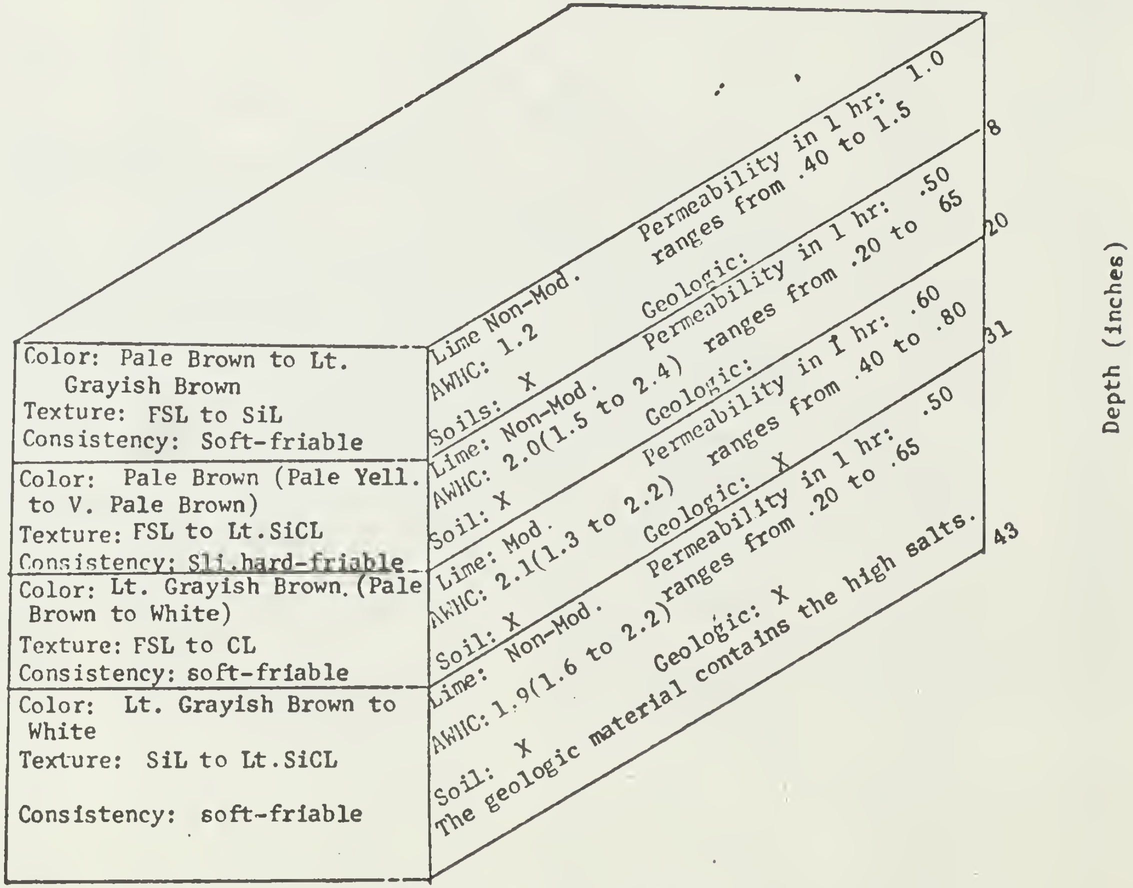
Remarks: Usable geologic strata above is about 60 feet thick below ele(est.) 3173 feet.

Figure 5

Generalized Reconstructed Profile SW$\frac{1}{4}$ Sec. 26, T. 3 S., R. 45 E.

pH 1-5	pH $CaCl_2$	EC X 10^3
8.0 (6.6-8.5)	7.4 (6.6-7.7)	< 2.0
8.3 (7.0-8.5)	7.7 (6.6-8.1)	< 2.0
8.7 (8.6-8.9)	8.0 (7.9-8.0)	< 2.0
8.5 (8.4-8.6)	8.0 (7.9-8.0)	< 2.0 to 11.0 *

*SAR 18 Ca+Mg1-5 18



Color: Pale Brown to Lt. Grayish Brown
Texture: FSL to SiL
Consistency: Soft-friable
Lime Non-Mod.
AWHC: 1.2
Soils: X
Permeability in 1 hr: 1.0 ranges from .40 to 1.5
Geologic:

Color: Pale Brown (Pale Yell. to V. Pale Brown)
Texture: FSL to Lt.SiCL
Consistency: Sli.hard-friable
Lime: Non-Mod.
AWHC: 2.0(1.5 to 2.4)
Soil: X
Permeability in 1 hr: .50 ranges from .20 to 65
Geologic:

Color: Lt. Grayish Brown (Pale Brown to White)
Texture: FSL to CL
Consistency: soft-friable
Lime: Mod.
AWHC: 2.1(1.3 to 2.2)
Soil: X
Permeability in 1 hr: .60 ranges from .40 to .80
Geologic: X

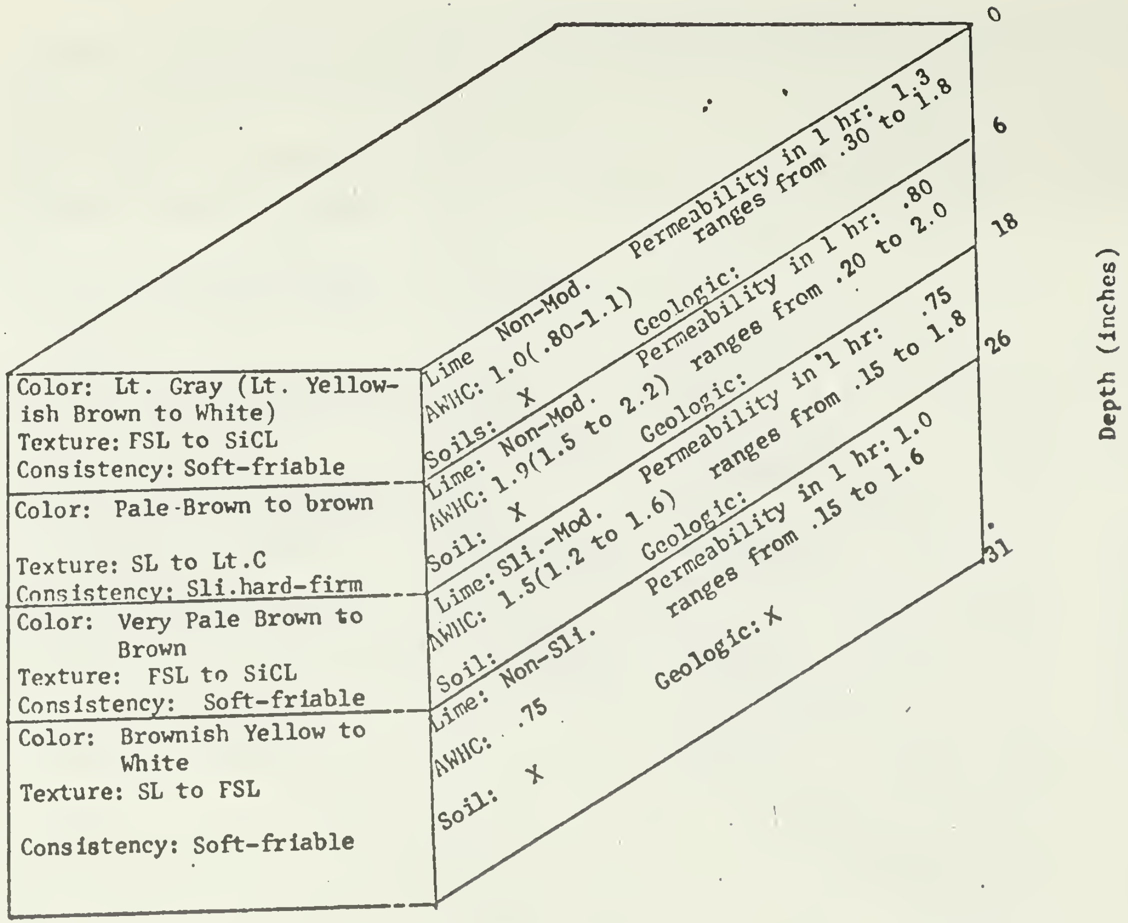
Color: Lt. Grayish Brown to White
Texture: SiL to Lt.SiCL
Consistency: soft-friable
Lime: Non-Mod.
AWHC: 1.9(1.6 to 2.2)
Soil: X
Permeability in 1 hr: .50 ranges from .20 to .65
Geologic: X
The geologic material contains the high salts.

Remarks: The saline and alkaline material is moderately to slowly permeable.

Figure 5 (cont)

Generalized Reconstructed Profile SE¼ Sec. 26, T. 3 S., R. 45 E.

pH 1-5	pH CaCl$_2$	EC X 10^3
8.3 (6.6-8.6)	7.3 (6.6-7.8)	< 2.0
8.2 (6.7-8.7)	7.5 (6.6-8.1)	< 2.0 to 4.0
8.4 (7.8-8.7)	7.8 (7.4-8.1)	< 2.0 to 6.0
8.4 (8.3-8.5)	8.1 (8.0-8.3)	< 2.0 to 10.0



Remarks: Saline material is moderately permeable and is not highly disperse.

Figure 5 (cont)

Generalized Reconstructed Profile: NE$\frac{1}{4}$ Sec. 34, T. 3 S., R. 45 E.

pH 1-5	pH CaCl$_2$	EC X 10^3
8.2 (7.6-8.5)	7.5 (7.0-7.7)	∠2.0
8.5 (8.1-8.8)	7.5 (7.3-7.8)	∠2.0
8.6 (8.1-8.8)	7.6 (7.4-8.0)	∠2.0 to 5.0
8.5 (8.3-8.7)	8.0 (7.8-8.2)	∠2.0 to 8.0

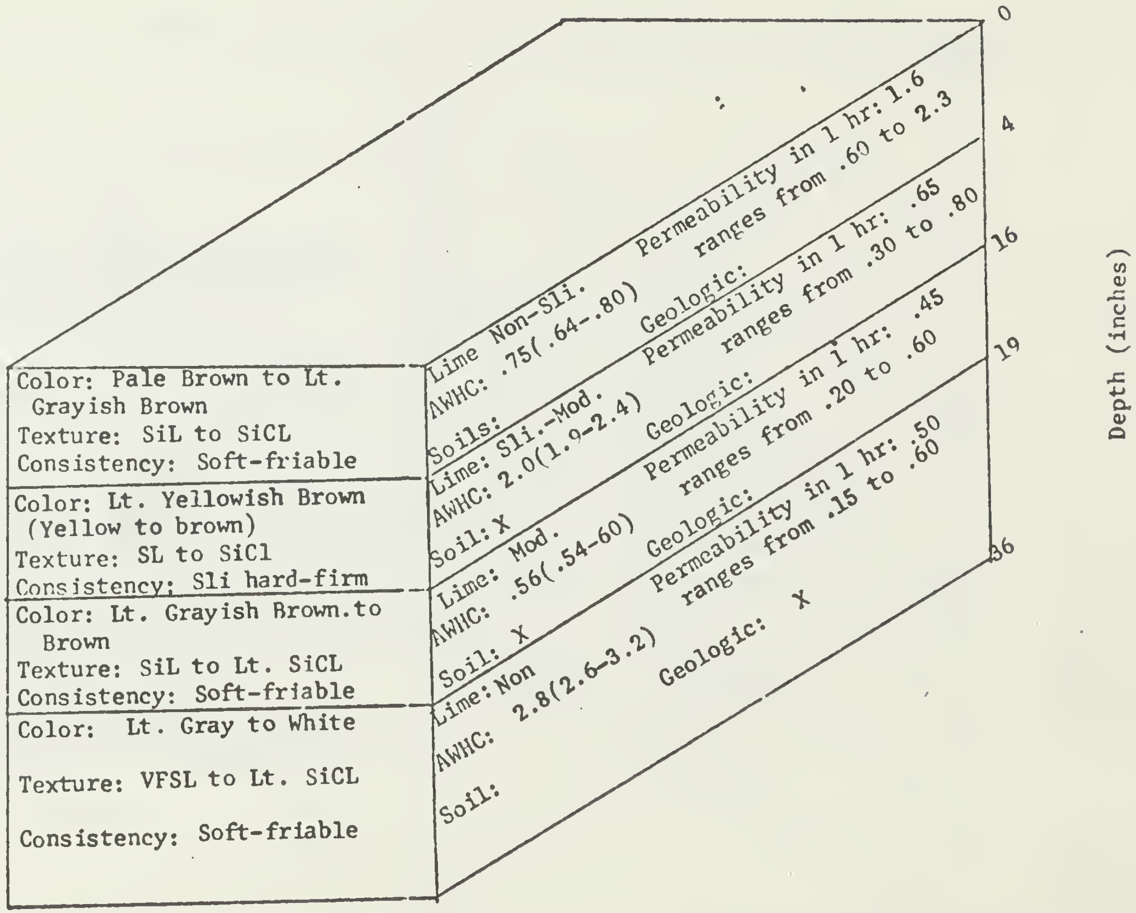
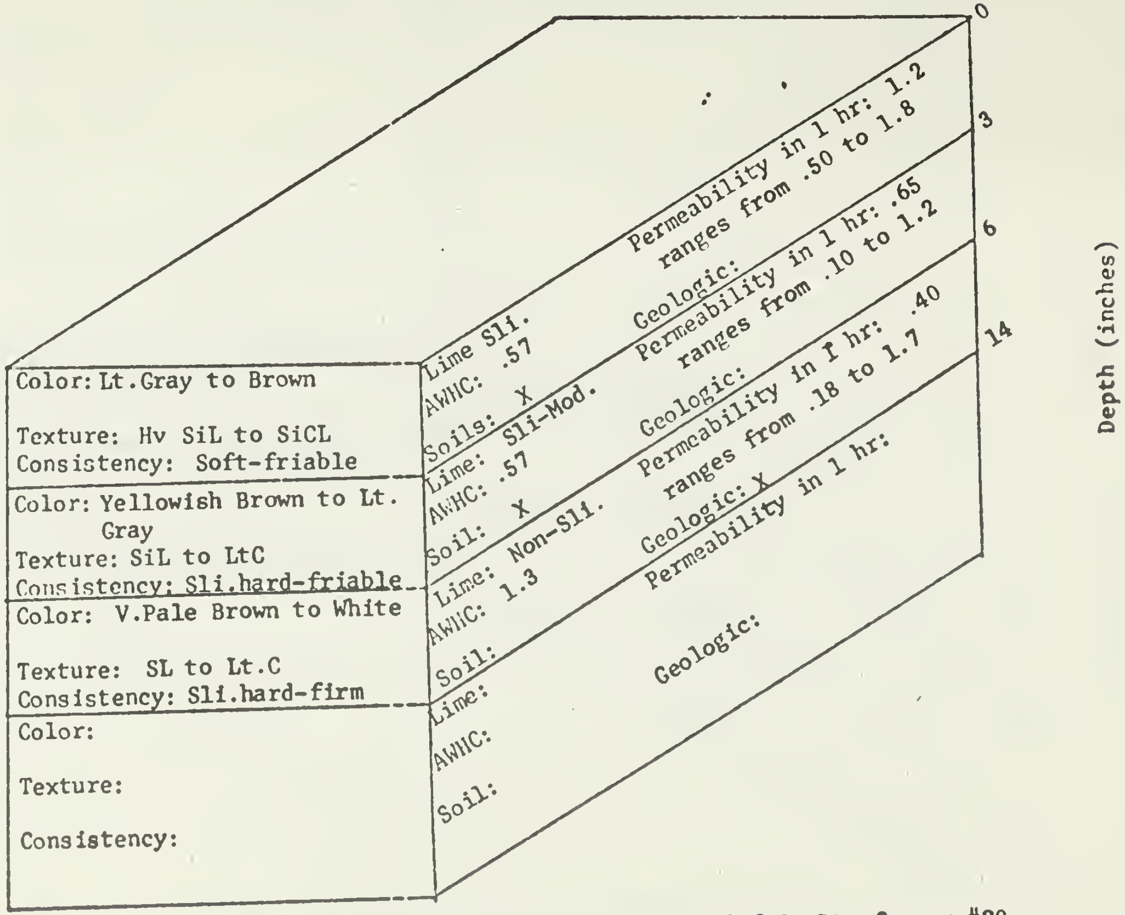


Figure 5 (cont)

Remarks: Use Sl soils and geologic strata from near LC Hole 13 for extra material.

Generalized Reconstructed Profile SW¼ Sec. 34, T. 3 S., R. 45 E.

pH 1-5	pH CaCl$_2$	EC X 10^3
8.3 (7.6-8.5)	7.7 (7.3-7.9)	< 2.0
8.4 (8.1-8.8)	7.8 (7.5-8.1)	< 2.0
8.7 (8.4-8.9)	8.0 (7.8-8.1)	< 2.0 to 6.0

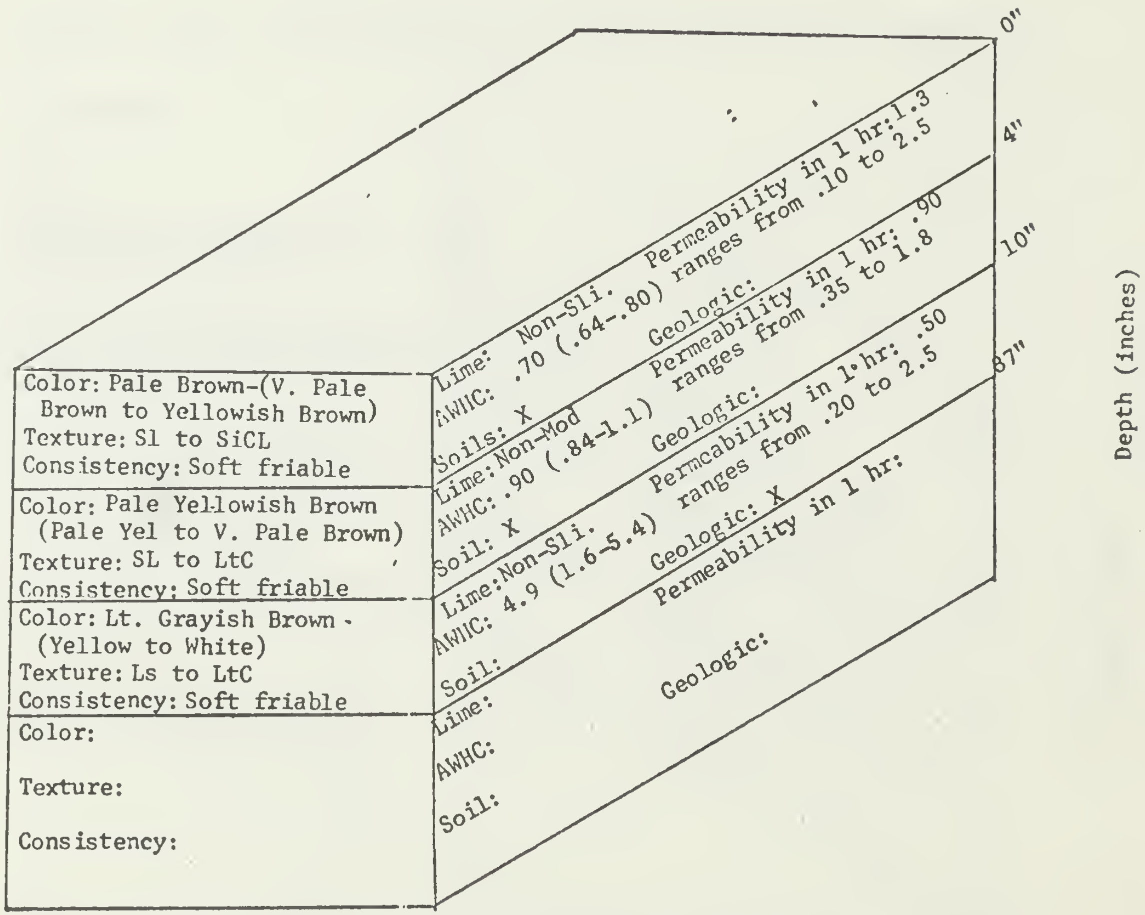


Remarks: Usable sandy overburden near LC hole 8, and fair Lt. C near #20.

Figure 5 (cont)

Generalized Reconstructed Profile SE¼, Sec. 34, T. 3 S., R. 45 E.

pH 1-5	pH $CaCl_2$	EC X 10^3
8.0 (7.0-8.6)	7.4 (7.1-7.7)	< 2.0
8.4 (7.2-9.0)	7.6 (7.4-7.9)	< 2.0
8.6 (8.4-8.9)	7.9 (7.5-8.1)	< 2.0 to 4.0

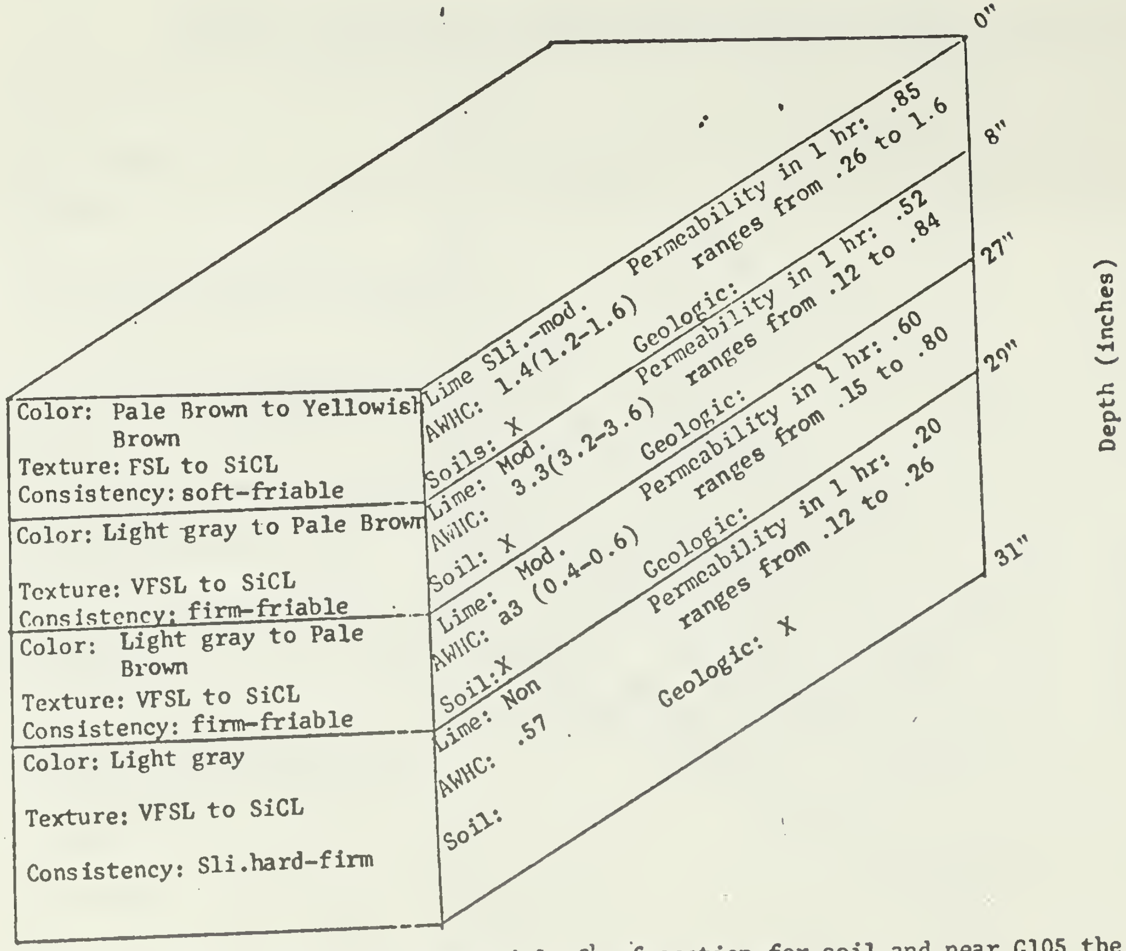

0"
4"
10"
37"
Depth (inches)
Color: Pale Brown-(V. Pale Brown to Yellowish Brown)
Texture: Sl to SiCL
Consistency: Soft friable
Color: Pale Yellowish Brown (Pale Yel to V. Pale Brown)
Texture: SL to LtC
Consistency: Soft friable
Color: Lt. Grayish Brown - (Yellow to White)
Texture: Ls to LtC
Consistency: Soft friable
Color:
Texture:
Consistency:
Lime: Non-Sli.
AWHC: .70 (.64-.80)
Soils: X
Permeability in 1 hr: 1.3 ranges from .10 to 2.5
Geologic:
Lime: Non-Mod
AWHC: .90 (.84-1.1)
Soil: X
Permeability in 1 hr: .90 ranges from .35 to 1.8
Geologic:
Lime: Non-Sli.
AWHC: 4.9 (1.6-5.4)
Soil:
Permeability in 1 hr: .50 ranges from .20 to 2.5
Geologic: X
Permeability in 1 hr:
Lime:
AWHC:
Soil:
Geologic:

Remarks: Selected geologic material should be used below 37". Near G105 the strata between ele. 3247 to 3221 may be suitable.

Figure 5 (cont)

Generalized Reconstructed Profile NE$\frac{1}{4}$ Sec. 2., T. 4 S., R. 45 E.

pH 1-5	pH $CaCl_2$	EC X 10^3
8.4 (7.7-8.5)	7.7 (7.5-7.7)	< 2.0
8.6 (8.1-8.5)	7.9 (7.7-8.0)	< 2.0
8.7 (8.3-9.3)	8.1 (7.7-8.2)	< 2.0 to 4.0
8.1 (7.9-8.3)	8.0 (7.7-8.2)	< 2.0 to 5.0

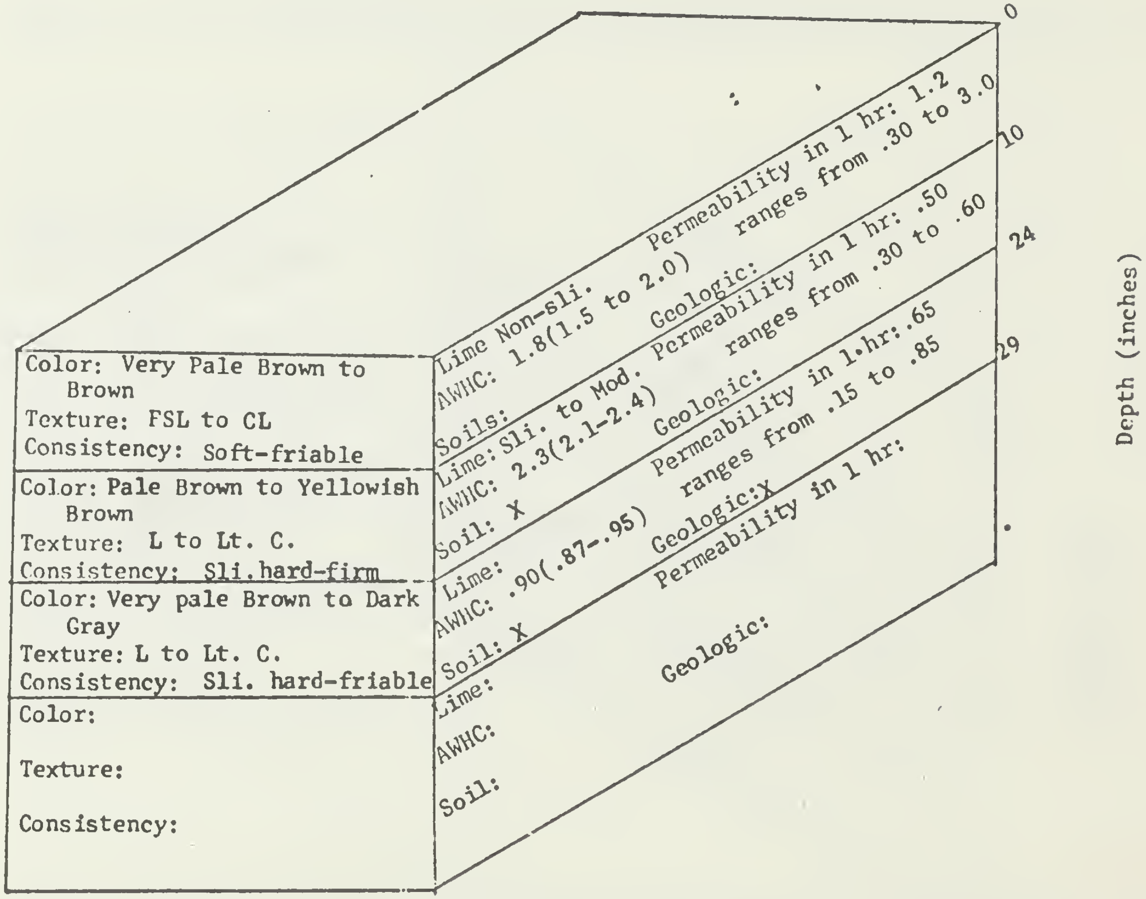

0"
8"
27"
29"
31"
Depth (inches)
Color: Pale Brown to Yellowish Brown
Texture: FSL to SiCL
Consistency: soft-friable
Color: Light gray to Pale Brown
Texture: VFSL to SiCL
Consistency: firm-friable
Color: Light gray to Pale Brown
Texture: VFSL to SiCL
Consistency: firm-friable
Color: Light gray
Texture: VFSL to SiCL
Consistency: Sli.hard-firm
Lime Sli.-mod.
AWHC: 1.4(1.2-1.6)
Soils: X
Permeability in 1 hr: .85 ranges from .26 to 1.6
Geologic:
Lime: Mod.
AWHC: 3.3(3.2-3.6)
Soil: X
Permeability in 1 hr: .52 ranges from .12 to .84
Geologic:
Lime: Mod.
AWHC: a3 (0.4-0.6)
Soil:X
Permeability in 1 hr: .60 ranges from .15 to .80
Geologic:
Lime: Non
AWHC: .57
Soil:
Permeability in 1 hr: .20 ranges from .12 to .26
Geologic: X

Remarks: Source of additional material; S$\frac{1}{2}$ of section for soil and near G105 the geologic strata between ele.(est.) 3250 and 3221 appears favorable.

Figure 5 (cont)

Generalized Reconstructed Profile: NW¼ Sec. 2, T. 4 S., R. 45 E.

pH 1-5	pH $CaCl_2$	EC X 10^3
8.2 (7.9-8.5)	7.8 (7.5-8.5)	< 2.0
8.5 (8.3-8.6)	7.8 (7.6-7.9)	< 2.0
8.5 (8.1-8.8)	8.0 (8.0-8.2)	< 2.0 to 10.0



Remarks: Potential source of materia, S½ of section for soil, geologic strata near G105 between ele.(est.) 3250 to 3221 and 3216 to 3194 near G106.

Figure 5 (cont)

Generalized Reconstructed Profile: SW$\frac{1}{4}$ Sec. 2., T. 4 S., R. 45 E.

pH 1-5	pH $CaCl_2$	EC X 10^3
8.2 (7.7-8.5)	7.6 (7.0-8.1)	∠ 2.0
8.3 (8.4-8.6)	7.7 (7.6-8.3)	∠ 2.0
8.5 (8.4-8.6)	7.9 (7.6-8.3)	∠ 2.0 to 5.0
8.6 (8.4-8.7)	7.9 (7.5-8.4)	∠ 2.0 to 10.0

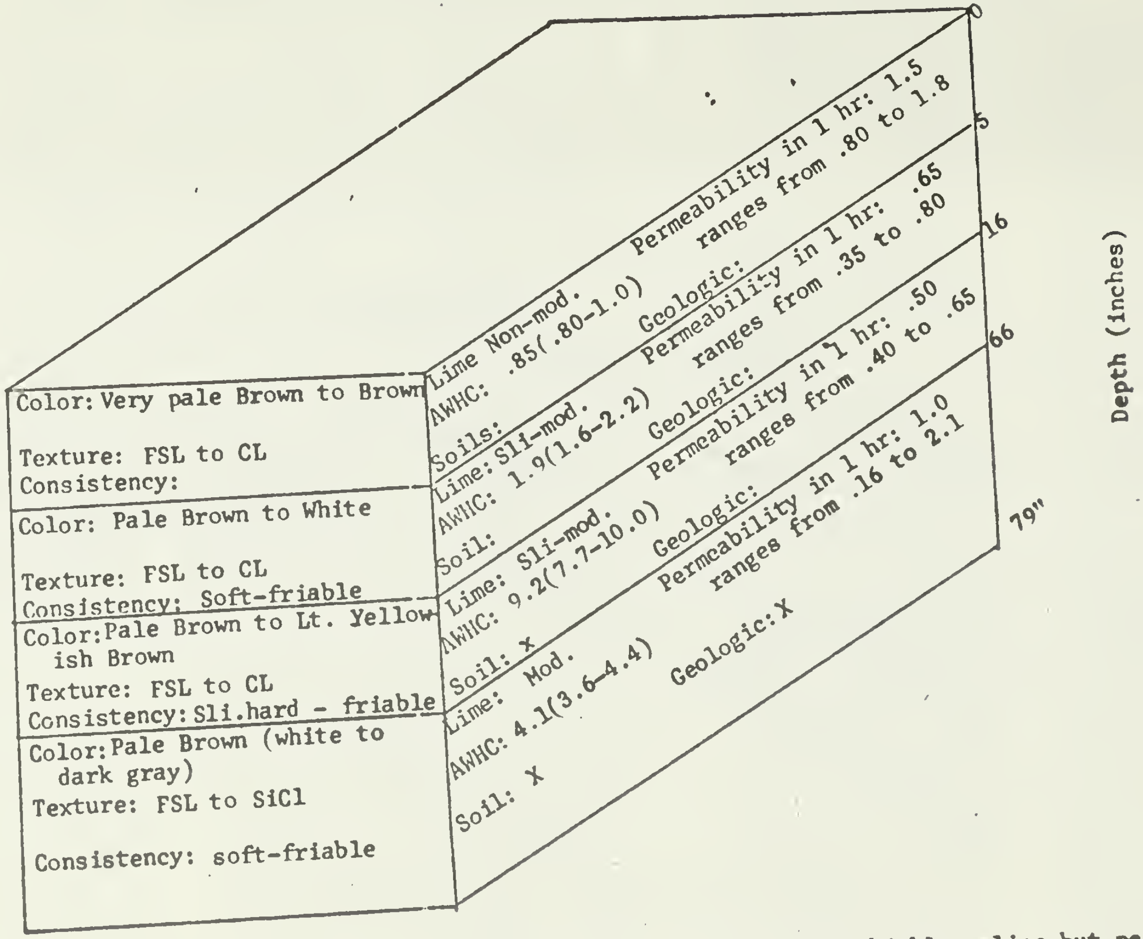
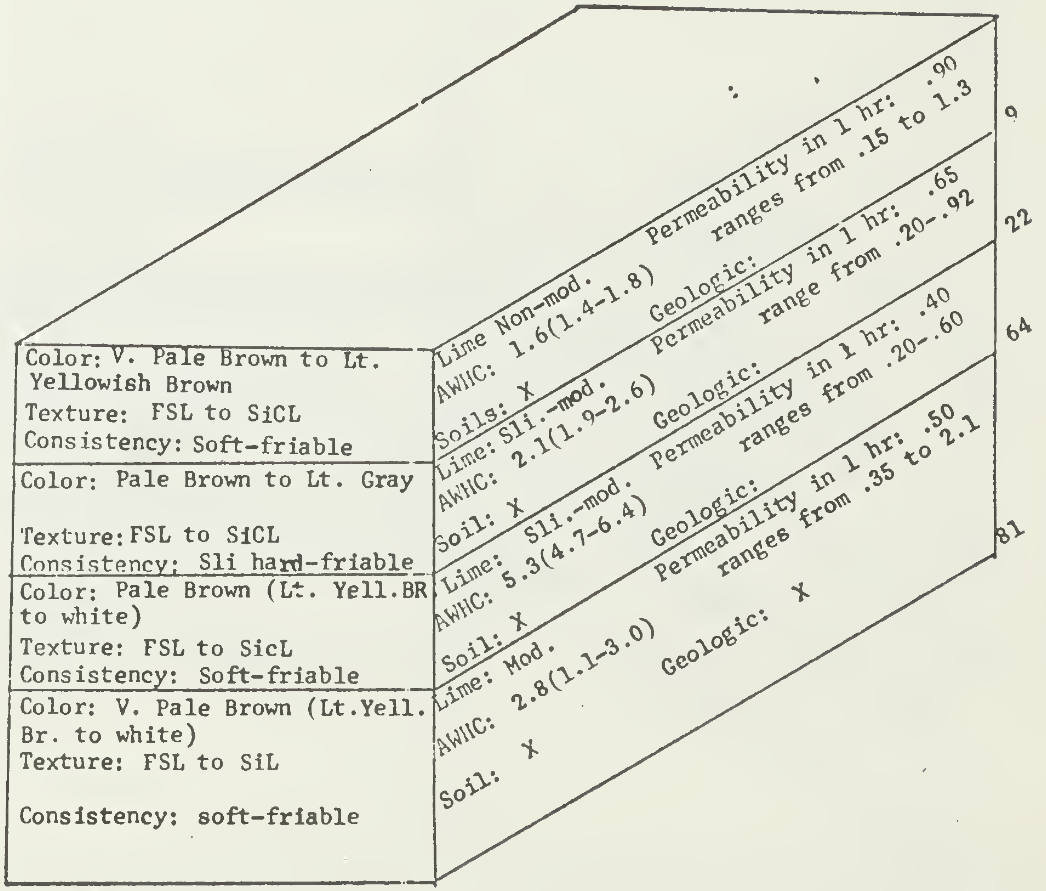


Figure 5 (cont)

Remarks: Alluvium in narrow valleys of small natural drains highly saline but permeable.

Generalized Reconstructed Profile: SE$\frac{1}{4}$ Sec. 2, T. 4 S., R. 45 E.

pH 1-5	pH CaCl$_2$	EC X 10^3
8.4 (8.4-8.7)	7.7 (7.0-7.8)	∠2.0
8.5 (8.3-8.7)	7.9 (7.4-8.0)	∠2.0
8.6 (8.4-9.3)	(7.7-8.1)	∠2.0
8.6 (8.6-9.5)	8.0 (7.9-8.1)	∠2.0 to 6.0



Color: V. Pale Brown to Lt. Yellowish Brown
Texture: FSL to SiCL
Consistency: Soft-friable

Lime Non-mod. Permeability in 1 hr: .90
AWHC: 1.6(1.4-1.8) ranges from .15 to 1.3
Soils: X Geologic:

Color: Pale Brown to Lt. Gray
Texture: FSL to SiCL
Consistency: Sli hard-friable

Lime: Sli.-mod. Permeability in 1 hr: .65
AWHC: 2.1(1.9-2.6) range from .20-.92
Soil: X Geologic:

Color: Pale Brown (Lt. Yell.BR to white)
Texture: FSL to SicL
Consistency: Soft-friable

Lime: Sli.-mod. Permeability in 1 hr: .40
AWHC: 5.3(4.7-6.4) ranges from .20-.60
Soil: X Geologic:

Color: V. Pale Brown (Lt.Yell. Br. to white)
Texture: FSL to SiL
Consistency: soft-friable

Lime: Mod. Permeability in 1 hr: .50
AWHC: 2.8(1.1-3.0) ranges from .35 to 2.1
Soil: X Geologic: X

Remarks: Very deep layers in valley alluvium contains layers of clean sand.

Figure 5 (cont)

burden effectively. Considerable stripping and stockpiling will be required. The best reclamation plan would provide adequate prepared slopes to use the upper 6 to 10 inches of overburden without stockpiling. Good quality overburden below the upper solum can be stockpiled, often with minimal adverse effect. Maximum use of the available quality overburden in these quarter sections and similar areas can yield about 35 inches of free working nonsaline and nonsodic material for surface use.

The sharply rolling terrain would be best reclaimed for range and wildlife. After the spoils are smoothed and resurfaced with good overburden, this area should respond and be much more productive than the present range. Average management after the area is returned to private use should be adequate to maintain a high level of production. Similar areas in public domain could have a high recreation potential based on hiking, picnicking, and upland bird hunting. Planting and transplanting browse plants can produce good deer habitat here.

A generalized reconstructed profile is shown on figure 5.

The Threemile Creek Valley including the valley alluvium and adjacent alluvial footslopes, fans, and terraces has good potential for irrigation development. Reclamation by Method 3 would retain this potential. In this section the massive amount of coal to be removed creates a significant problem in the alluvial valley area. Removal of the coal will leave the valley about 30 feet below the unmined valley to the west. Maximizing the use of good quality soil would produce a 144-acre field with an average soil depth between 7 and 8 feet. The depressed relief would reduce the potential of this tract. One method of salvaging the agriculture potential of these valley lands is to relocate them. Another plan would provide an outlet drain for surface water. An outlet drain of this depth could adversely affect the unmined land to the west. The following plan for this section maximizes the use of quality overburden.

Mining operations should be planned to progress from the north section line southward. Field No. 1 would contain 200 acres and extend about 1,100 feet south. All of the usable overburden in the north two-thirds of the section should be stripped and stockpiled as mining operations progresses southward. Where possible, the mining plan should provide for placement of the upper 10 to 16 inches of good quality overburden on preshaped spoils without stockpiling. The average depth of good quality overburden in this field would be about 50 inches. Native plant species would be used for revegetation; but depending on the post mining surface relief, the area could have good potential for dry farming.

Field No. 2 would extend 1,970 feet south of Field No. 1 and would contain 144 acres. The quality overburden from this field would have been stripped and used in Field No. 1. After mining and removal of the 60± feet of coal the raw spoils should be shaped to a uniform 2 percent slope and the high quality overburden relocated here as the valley of Threemile Creek is mined. The reconstructed profile would have about 8 feet of high quality overburden, consisting of alluvial soil material and minor amounts of geologic material. The reconstructed profile will have good potential for producing irrigated or dry farmed crops. Production of dry farmed or irrigated crops in this area would develop habitat suitable for upland birds including pheasants, also antelope and deer. Escape cover would be available in the surrounding range land.

After mining and relocation of the valley soils Threemile Creek Valley and adjacent slopes in Section 2, T. 4 S., R. 45 E. would be below the original elevation. This depressed area would amount to 96 acres. To prevent water movement from the mined area into the unmined alluvium, the walls could be sealed off with impermeable shale forming a deep pond. This pond could be a valuable asset by providing stock water for the surrounding range and recreation as a picnic and fishing area. Surface runoff may be supplemented by floodflows from Otter Creek to provide water to irrigate the relocated field No. 2 if this becomes a desirable option in the future. Facilities to provide the supplemental water from the creek would include a pumping plant with 50-foot lift into a 3.4 mile contour ditch.

A generalized profile is shown on figure 5.

The soil conditions depicted are typical except for the depth. Field 1 will have about 50 inches of soil material.

Figure 5 shows the generalized reconstructed profiles representing the projected post mining conditions that are attainable in each 1/4 section investigated. Values and ranges used in developing the average condition are also shown where applicable. Three of these profiles are relatively typical of the anticipated post mining conditions resulting from the three alternate methods described and are mentioned in the narrative. The Montana Surface-Mining Law requires characterizing the reconstructed profile. The profiles described in figure 5 meet State requirements.

The reconstructed profile should be shaped and prepared for seeding using any method that will reduce surface runoff and increase infiltration of precipitation. The quality of soil and slope gradient should be major determinants of seed bed preparation, fertilization, and plant mixtures to be used in reclamation plans.

Native grass mixtures should most likely include green needle grass (Stipa viridula), western wheet grass (Agropyron smithii), side oats gramma (Bouteloua curtipendula), little bluestem (Andropogon scoparius), prairie junegrass (Koleria cristata), blue grama (Boutelous gracillis) and needle-and-thread (stipa comata). The proportion of each grass should depend on the soil quality, slope gradient, exposure and surface drainage. Soil quality factors influencing the plant mixture include texture, infiltration, moisture retention, internal drainage, and salinity and sodicity.

Shrubs would include four-winged saltbush, silver sage, (Artmesia cana) and big sage (Artmesia tridenta). Sedges may be of value in some saline seeding conditions. Cottonwood willows, and woody shrubs can also contribute to the stability of the surface material. These diciduous trees and shrubs develop quickly but may require limited watering until a balance between the top and roots is achieved. Plastic covered depressions around the base of the newly planted trees can prevent weed growth and concentrate the precipitation near the tree roots. This method may provide adequate moisture for transplanted trees in this area.

Planting on the contour has merit but the rows should not be deep enough to accumulate precipitation in quantities that would accelerate erosion if the water overtops the rows. Random basins gouged out with special equipment appears to be well suited for moderate to steep slopes and moderate to slowly permeable soils.

In Montana, surface-mined land will be reclaimed by revegetating with native vegetation. During the reclamation period, estimated to require 3-7 years, no grazing or at least low intensity or winter grazing should be practiced. Average management should be adequate when returned to nonsupervised management and/or private ownership.

Mining operations will reduce the agricultural potential of this land to near zero for 3 to 7 years. During the mining operations minor impacts will be made on the air and water, but major impacts will be made on the vegetative cover in local tracts. Wildlife and domestic livestock will be displaced temporarily. This may result in changes in the population density of wildlife species, possibly an increase in sharptail grouse and antelope and a decrease of mule deer after reclamation, and the range can be improved. Another benefit can be the reduction of erosion of the uplands and sediment load of streams. Unless big sage is included in the revegetation plan, the present small population of sage grouse will be permanently displaced. Their use area is largely in adjacent sections.

Within the limits of Montana law the alternate methods of reclamation must evolve around the amount and location of quality overburden suitable for use at or near the surface of reshaped lands. The three methods presented earlier reflect these constraints. It is quite likely some of this area could be reclaimed for agriculture purposes other than range.

Alternate Method 3 which attempts to preserve present agricultural development potential of sizeable tracts and some enhancement of rehabilitated areas by combining small tracts of high quality soil should be considered in most mining plans.

Description of Typical Profiles

1. 9001 series (Haverson series).

The 9001 series consists of well-drained medium-texture soils that are more than 60 inches deep. These soils formed in loamy alluvium under short and mid grasses. Slopes are 0 to 4 percent, and elevation ranges from 2,700 to 3,500 feet. The average annual precipitation is 14 inches, the average annual soil temperature is 47 to 49° F., and the frost-free season is 108 to 120 days. These soils are associated with 9003, 9010, and 9004 soils.

Typically the surface layer is light brownish-gray silt loam about 6 inches thick. The subsoil and substratum are calcareous grayish-brown and light brownish-gray stratified silt loam, fine sandy loam, and silty clay loam.

The 9001 soils are used mainly for irrigated and dry-farmed hay and small grains.

Representative Profile:
Location: 700 feet north and 600 feet east of SW corner of Sec. 2, T. 4 S., R. 45 E.
Classification: Ustic Torrifluvents, fine-loamy, mixed (Calcareous), Mesic
Slope: 2% Class: Gently sloping kind: Plane Aspect: West
Control section limits - Upper: 25 cm Lower: 100 cm
Site Number: 2 County: Powder River
Month sampled: October Stoniness: Class 0
Permeability: Moderate Elevation: 3,080 feet
Drainage Class: Well drained Vegetation: Grasses and Forbs
Physiography: Alluvial or Colluvial Fans Precipitation: 35.6 cm
Microrelief: Frost Polygons
Parent Material: Alluvium interbedded sandstone and shale

A1 0-5 cm (0-2 inches) — Pale brown (10YR6/3) crushed dry peds; brown (10YR4/3) crushed moist peds; silt loam; crumb structure; soft, very friable, slightly sticky, slightly plastic, many fine roots; many very fine and fine continuous tubular pores; pH 7·3 (water 1:1); mildly effervescent (HCl); clear wavy boundary.

AC 5-21 cm (2-8 inches) -- Pale brown (10YR6/3) crushed dry brown (10YR4/3) crushed moist peds; silt loam; very weak fine and medium subangular blocky structure separating to medium granular structure; slightly hard, very friable, slightly sticky, slightly plastic; many very fine and fine roots throughout horizon; many very fine and fine tabular discontinuous pores; pH 7.5 (water 1:1); moderately effervescent (HCl); clear wavy boundary.

C1 21-84 cm (8-33 inches) -- Pale brown (10YR6/3) crushed dry peds; brown (10YR4/3) crushed moist peds; light loam; slightly hard, very friable, nonsticky, slightly plastic; common very fine and fine roots throughout horizon; common to many very fine and fine tubular discontinuous pores; pH 7.6 (water 1:1); moderately effervescent (HCl); clear wavy boundary.

C2 84-124 cm (33-49 inches) — Pale brown (10YR6/3) crushed dry peds; yellowish brown (10YR5/4) crushed moist peds; stratified silt loam and loam; few stratifications which are sandy loam and of 3 cm average thickness; slightly hard, very friable, slightly sticky, slightly plastic; few very fine and fine roots throughout horizon; many very fine and fine tubular discontinuous pores; pH 7.5 (water 1:1); moderately effervescent (HCl); clear wavy boundary.

C3 124-152 cm (49-60 inches) -- Pale brown (10YR6/3) crushed dry peds; yellowish brown (10YR5/4) crushed moist stratified loam and silt loam; stratifications which are loam sand and of 3 cm total thickness; slightly hard, very friable, slightly sticky, slightly plastic; few very fine roots throughout horizon; few very fine and fine tubular discontinuous pores; pH 7 (water 1:1); moderately effervescent (HCl).

Remarks: Mapped HC - Haverson silt loam 0-2 percent slopes. Sampled in banks of drainage north of trail (W.M.L. J.M.S., W.P.V.)

9001 silt loam (0-2 percent slope) $\frac{01}{A1M}$

This soil occurs on flood plains and stream terraces. It is underlain by stratified alluvium at a depth of 20 inches or more. It has the profile described as typical for the series. Included with this soil is mapping are areas of Glenberg fine sandy loam less than 5 acres in size.

This soil has slow runoff and moderate permeability. The available water capacity is 9 to 11 inches for a 5-foot depth. The organic matter content is low, and the fertility is medium. Plant roots penetrate deeply. Fallowed soil blows easily.

This soil is used for dry-farmed or irrigated small grains and alfalfa for hay or seed. Alfalfa hay, wheat, barley, and oats grow well on irrigated soil.

2. 9002 series (Thurlow series)

The 9002 series consists of well-drained, moderately fine textured soils that are more than 60 inches deep. These soils formed in deep silty clay loam alluvium in stream terraces, fans, and foot slopes on the uplands. The native vegetation is mid and short grasses. Slopes are 0 to 15 percent, and elevation ranges from 3,000 to 4,000 feet. The average annual precipitation is 14 inches, the average annual soil temperature is 47 to 49° F., and the frost-free season is 108 to 120 days. These soils are associated with 9003, 9004, and 90010 soils.

Typically the surface layer is grayish-brown silty clay loam about 6 inches thick. The subsoil is dark grayish-brown, light olive-brown, and pale-brown silty clay loam about 18 inches thick. The substratum is pale-brown calcareous silty clay loam and pale-yellow calcareous silty clay.

9002 soils are used mainly for dry-farmed and irrigated small grains and alfalfa. A small acreage is used for pasture.

Representative Profile:
Location: 2200 feet south and 800 feet west of the NE corner of Sec. 34, T. 3 S., R. 45 E.
Classification: Ustollic Haplargids; fine, montmorillonitic, mesic
Slope: 6% Class: Moderately sloping Kind: Plane Aspect: Northwest
Control section limits - Upper: 8 cm. Lower: 33 cm.
Site Number: 3 County: Powder River
Month sampled: October Stoniness: Class 0
Permeability: Moderately slow Elevation: 3180 Feet
Drainage Class: Moderately well drained Vegetation: Grasses and Forbs and shrubs
Physiography: Alluvial or Colluvial fans Precipitation: 35.6 cm.
Parent Material: Residual material, local colluvium or solifluctate calcareous shale

A1 0-8 cm. (0-3 inches) — Pale brown (10YR6/3) crushed dry peds; brown (10YR4/3) crushed moist peds; light clay; weak fine and medium subangular blocky structure separating to granular structure; soft, very friable, sticky, plastic; many very fine and fine roots throughout horizon; many fine tubular continuous pores; pH 7.3 (water 1:1); noncalcareous (HCL); clear smooth boundary.

B2 8-33 cm. (3-13 inches) -- Light yellowish brown (10YR6/4) crushed dry peds; brown (10YR4/3) crushed moist peds; clay; weak coarse prismatic structure separating to weak to moderate medium and coarse subangular blocky structure; hard, firm, sticky, plastic; many very fine and fine roots throughout horizon; many very fine and fine tubular continuous pores; pH 7.2 (water 1:1); mildly effervescent (HCl); clear wavy boundary.

B3Ca 33-46 cm. (13-18 inches) -- Light yellowish brown (10YR 6/4) crushed dry peds; dark yellowish brown (10YR4/4) crushed moist peds; light clay; weak coarse prismatic structure separating to weak to moderate medium and coarse subangular blocky structure; hard, firm, sticky, plastic; many very fine and fine roots throughout horizon; many very fine and fine tubular continuous pores; pH 7.4 (water 1:1); moderately effervescent (HCL); clear wavy boundary.

C1Ca 46-64 cm. (18-25 inches) — Light gray (2.5Y7/2) crushed dry peds; light yellowish brown (2.5Y6/4) crushed moist peds; heavy silty clay loam; massive structure; hard, firm, sticky, plastic; common very fine and fine roots throughout horizon; common fine tubular continuous pores; pH 7.2 (water 1:1); violently effervescent (HCl); clear smooth boundary.

C2Ca 64-101 cm. (25-40 inches) -- Pale yellow (2.5Y7/4) crushed dry peds; light yellowish brown (2.5Y6/4) crushed moist peds; silty clay loam; massive structure; soft, very friable, slightly sticky, slightly plastic; few very fine roots throughout horizon; few very fine tubular pores; pH 8.0 (water 1:1); moderately effervescent (HCl); clear smooth boundary.

C3 101-132 cm. (40-52 inches) -- Light gray (2.5Y7/2) crushed dry peds; light brownish gray (2.5Y6/2) crushed moist peds; heavy silt loam; massive structure; slightly hard, friable, slightly sticky, slightly plastic; very fine roots throughout horizon; few very fine tubular pores; few soft medium gypsum crystals; pH 7.9 (water 1:1): mildly effervescent (HCL); clear smooth boundary.

C4Cs 132-152 cm. (52-60 inches) -- Light grey (2.5Y7/2) crushed dry peds; light brownish gray (2,5Y6/2) crushed moist peds; clay; massive structure; hard, firm, sticky, plastic; very fine roots throughout horizon; few very fine tubular pores; common soft medium gypsum crystals; pH 7.9 (water 1:1); noncalcareous (HCL),

Remarks: Mapped in MG. - Midway-Elso. Mapping unit, J.M.S., W.M.L., W.P.V.

9002 series (0-3 percent slope) $\frac{02}{A1N}$

This soil is on terraces, fans, and foot slopes. It has a profile described as typical for the series. Associated series include 9003 and 9008, It occurs here as foot slopes and fans here.

Runoff is slow and permeability is moderately slow. The available water capacity is 9 to 11 inches for a 5-foot depth. Organic matter content is medium, and fertility is high. The hazard of erosion is slight. Small acreages of this soil are used for range.

9002 series (3-6 percent slopes) $\frac{02}{B2N}$

This soil occurs on foot slopes and fans in the uplands. It is underlain by clayey shale beds at a depth of more than 5 feet. This soil is similar to $\frac{02}{A1N}$ except for the stronger slopes and the increased runoff and erosion hazard. This soil is associated with 9003 and 9006 series. This soil is used for range. It is also used for dry farming and produces small grains and alfalfa.

9002 series (6-12 percent slopes) $\frac{02}{C3N}$

This soil occurs on foot slopes and fans in the uplands. It is underlain by clayey or silty shale beds generally at a depth of more than 5 feet. Runoff and erosion hazard is moderate to severe. This soil is used for range. It is also used for dry-farmed small grains and alfalfa grown for hay and seed. It is most often used for range when associated with 9003 soils as it is here.

3. 9003 series (Midway series)

The 9003 series consists of well-drained, moderately fine textured soils that are underlain by shale, generally at a depth of less than 20 inches. These soils are on uplands under a cover of short grasses. Slopes are 2 to 75 percent, and elevation ranges from 3,000 to 4,000 feet. The average annual precipitation is 14 inches, and the average annual soil temperature is 47 to 49° F., and the frost-free season is 108 to 120 days. These soils are associated with 9002, 9004, 9006, and 90005 soils.

Typically the surface layer is light yellowish-brown clay loam and clay 7 inches thick. The substratum is light brownish-gray interbedded silty, clayey, and sandy material underlain by softly consolidated pale-olive clayey shale at a depth of 7 to 20 inches. Salt and gypsum crystals are interbedded between the shale layers below a depth of 10 inches.

Representative Profile:
Location: 1,700 feet north and 2,400 feet east of the SW corner of Sec. 34, T. 3 S., R. 45 E.
Classification: Ustic torriorthents, clayey, montmorillonitic (Calcareous) mesic, shallow
Slope: 19% Class: Steep Kind: Convex Aspect: Southwest
Control Section Limits - Upper: 25 cm Lower: 100 cm
Site Number: 1 County: Powder River
Month sampled: October Stoniness: Class 0
Permeability: Slow Elevation: 3240 Feet
Drainage Class: Well Drained Vegetation: Grasses and forbs
Physiography: Rolling or hilly Uplands Precipitation: 35.6 cm.
Parent Material: Residual material, local colluvium or solifluctate interbedded shale and siltstone.

A1 0-8 cm. (0-3 inches) — Light brownish gray (2.5Y6/2) crushed; dark grayish brown (2.5Y4/2) crushed; clay loam; weak to moderate fine and medium granular structure; soft, friable, sticky, plastic; many very fine and fine roots throughout horizon; few to common very fine and fine tubular continuous pores; pH 7.3 (water 1:1); moderately effervescent (HCl); clear wavy boundary.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

OTTER CREEK STUDY SITE
OTTER CREEK COAL FIELD

SOIL SERIES DESCRIPTIONS

DRAWN. H.B.W. SUBMITTED
TRACED RECOMMENDED
CHECKED. H.B.W. APPROVED
BILLINGS, MONTANA SHEET 1 OF 5 JULY, 1975 1305-600-29

AC 8-16 cm. (3-6 inches) — Light brownish-gray (2.5YS/2) crushed dry peds; grayish brown (2.5YS/2) crushed moist peds; silty clay loam; weak fine and medium subangular blocky structure separating to weak to moderate fine and medium granular structure; slightly throughout horizon; common very fine and fine tubular continuous pores; pH 7.6 (water 1:1); mildly effervescent (HCL); clear smooth boundary.

C1Ca 16-30 cm. (6-12 inches) -- Light gray (5Y7/2) crushed dry peds; olive gray (5Y5/2) crushed moist peds; silty clay loam; weak fine and medium platy structure; slightly hard, friable, sticky, plastic; few very fine and fine roots throughout horizon; few very fine and fine tubular pores; few soft fine gypsum crystals; pH 8.8 (Thymol Blue); moderately effervescent (HCl); clear smooth boundary.

C2 30-50 cm. (12-19 inches) -- Light gray (5Y7/2) crushed dry peds; olive gray (5Y5/2) crushed moist peds; silty clay; weak medium platy structure; slightly hard, friable, very sticky, plastic; few very fine roots throughout horizon; few very fine tubular pores; few soft fine gypsum crystals; pH 7.6 (water 1:1); mildly effervescent (HCl); abrupt smooth boundary.

C3 50-100 cm. (19-39 inches)-- Light gray (5Y7/2) crushed dry peds; olive gray (5Y5/2) crushed moist peds; weakly consolidated interbedded shale and siltstone; very coarse platy structure; pH 7.6 (water 1:1); mildly effervescent (HCL); clear smooth boundary.

C4 100-153 cm. (39-60 inches) -- Yellow (10Y8/6) crushed dry peds; yellowish brown (10YR5/6) crushed moist peds; weakly consolidated interbedded shale and siltstone; very coarse platy structure; pH 7.3 (water 1:1); moderately effervescent (HCL).

Remarks: Mapped mg. Midway-Elso Mapping Unit J.M.S., W.P.V.

9003 series (2-7 percent slopes) $\frac{03}{B2N}$

This soil occurs on divides and ridges and along the lower foot slopes bordering natural drains. The surface soil is slowly permeable and at depths of more than 2 feet roots penetrate only through cleavage planes and fractures in the shale. The subsoil consists of highly weathered shale and is underlain by shale at about 20 inches. The subsoil is often saline and/or sodic.

The erosion hazard is slight to moderate and the runoff and sediment hazard is not excessive. This soil is used for range.

9003 series (7-12 percent slopes) $\frac{03}{02N}$, $\frac{03}{C3N}$, $\frac{03}{C4}$, $\frac{03}{C2M}$.

This soil occupies the intermediate slopes below the ledge forming sandstone bluffs and the intermittent natural drains. Two textural phases, medium loams and moderately fine loamy and three erosional phases were mapped separately.

The erosional phases include slight, moderate, and severe. These soils range from the typical series profile and include clayey raw soils forming from clay shale and medium loamy soils forming from siltstone. Small inclusions of rockland 03S and 04 also occur in small tracts.

9003 series (12-20 percent slopes) $\frac{03}{03N}$, $\frac{03}{D4N}$

This mapping unit occupies the upper foot slopes that are divided by tabular divides and weak ridges in the uplands. A dominant feature is the exposed clayey and silty shale and sandstone that occurs on ridges, knobs, and short steep slopes along natural drainages.

These soils are moderately erosive and contribute sizable amount of water and sediment to the natural drainage system tributary to the Yellowstone River. Two erosional phases were mapped $\frac{03}{C3N}$ and $\frac{03}{D4H}$.

These soils are moderately to slowly permeable and are too shallow and too steep for cultivation. The valley sides are often cut by steep sided natural drains and gullies that join to form larger drainage ways. Native vegetation includes mid and short grasses, forbes, and salt tolerant sedges.

9003 series (20-35 percent slopes) $\frac{03}{E3N}$, $\frac{03}{E4N}$

This soil is immediately below cap rock ledges in locations similar to $\frac{03}{F4N}$. The slope gradient is lower and shale exposures are less dominant. Ponderasa Pine occur in moderate to good stands and loose flag rock ranging from 2 - 12 inch in size are common. The soil profile is quite typical of the series.

9003 series (35-75 percent slope) $\frac{03}{F4N}$

This soil lies in patches around shale outcrops. Thick massive ledge forming hard sandstone cap rock is common. The upper slope just below the escarpment is often strewn with scattered large massive rocks of sandstone and many shards of thin bedded sandstone that breaks off in slabs. Another dominant feature is the large amount of silty, clayey, and sandy shale and sandstone outcrops on the very steep south-facing slopes. Occasional lignite seams can be seen in the shale exposures.

These soils are low in organic matter content and fertility. Runoff is rapid and water erosion hazard is severe where shale outcrops, and these areas contribute large amounts of runoff water and sediment to the intermittent natural drains and streams that drain into the Yellowstone River.

The native vegetation includes mid and short grasses, big sage, shrubs, and Ponderosa Pine. These soils are used for range.

9003S series (3-12 percent slopes) $\frac{03S}{B2N}$, $\frac{03S}{C2M}$

This soil comprises rockland tracts at lower elevation than the tabular divides of the uplands. The vegetative cover is typically ponderasa pine and mixed grasses. Massive blocks of indurated sandstone occur at random and along the edge of most areas. The soils on the intervening slopes are shallow to shale but have a well developed population of mid and short grasses, locally small shale outcrops are common. These soils are used for range.

4. 9004 series (McRae series)

The 9004 series consists of well-drained silt loam soils that are more than 5 feet deep. These soils formed in deep alluvial materials on fans, terraces, stream terraces, and foot slopes. The native vegetation is mid and short grasses. Slopes are 0 to 12 percent, and elevation ranges from 3,000 to 3,500 feet. The average annual precipitation is 14 inches, the average annual soil temperature is 47 to 49° F., and the frost-free season is 108 to 120 days. These soils are associated with 90010, 9007, and 9003 soils.

Typically the surface layer is grayish-brown silt loam about 9 inches thick. The subsoil and substratum are pale-brown calcareous silt loam that extends to a depth of more than 60 inches.

The 9004 soils are used for small grains and alfalfa grown for hay or seed. A large acreage is range.

Representative Profile:

Location: 1,000 feet east and 300 feet south of NW corner of Sec. 2, T. 4 S., R. 45 E.

Classification: Ustollic camborthids, fine-loamy, mixed, mesic

Slope: 12% Class: - Kind: Convex Aspect: Northeast

Control Section Limits - Upper: 25 cm. Lower: 100 cm.

Site Number:	6	County:	Powder River
Month Sampled:	October	Stoniness:	Class 0
Permeability:	Moderate	Elevation:	3,280 Feet
Drainage Class:	Well-drained	Vegetation:	Grasses, forbs, and shrubs
Physiography:	Rolling or hilly Uplands	Precipitation:	35.6 cm.
Parent Material:	Unconsolidated mineral sediments Interbedded sandstone and shale		

A1 0-8 cm. (0-3 inches) — Dark yellowish brown (10YR4/4) crushed dry peds; dark brown (10YR3/3) crushed moist peds; loam; weak fine subangular blocky structure separating to granular structure; soft, very friable, slightly sticky, slightly plastic; many very fine and fine roots throughout horizon; many very fine tubular discontinuous pores; pH 7.3 (water 1:1); noncalcarious (HCL); clear smooth boundary.

B2 8-15 cm. (3-6 inches) — Yellowish brown (10YR5/4) crushed dry peds; brown (10YR4/3) crushed moist peds; loam; moderate medium prismatic structure separating to moderate medium subangular. blocky structure separating to granular structure; slightly hard, friable, slightly sticky, slightly plastic; common to many very fine and fine roots throughout horizon; many very fine tubular discontinuous pores; pH 7.2 (water 1:1); mildly effervescent (HCl); clear wavy boundary.

B3Ca 15-50 cm. (6-20 inches) — Light yellowish brown (2.5Y6/4) crushed dry peds; light olive brown (2.5Y5/4) crushed moist peds; silt loam; moderate medium prismatic structure separating to moderate medium subangular blocky structure separating to granular structure; slightly hard, friable, slightly sticky, slightly plastic; few to common very fine roots throughout horizon; many very fine tubulor discontinuous pores; 20 percent soft fine masses of lime; pH 7.6 (water 1:1); moderately effervescent (HCl); clear wavy boundary.

C1Ca 50-69 cm. (20-27 inches) — Light gray (2.5Y7/2) crushed dry peds; light yellowish brown (2.5Y6/4) crushed moist peds; silt loam massive structure; slightly hard, friable, slightly sticky, slightly plastic; very fine and fine roots in cracks; present very fine tubulor discontinuous pores; 40 percent soft medium masses of lime; 15 percent sandstone fragmento 2-8 cm.; pH 7.8 (water 1:1); violently effervescent (HCL), clear smooth boundary.

C2 69-152 cm. (27-60 inches) — Pale Yellow (2.5Y7/4) crushed dry peds; light olive brown (2.5Y5/4) crushed moist peds; light clay loam; hard, friable, slightly sticky, slightly plastic; very fine roots throughout horizon; few very fine tubular discontinuous pores; pH 7.9 (water 1:1); moderately effervescent.

Remarks: Mapped CN-Cushman-Elso, W.H.L., J.H.S., W.P.V.

9004 series loam (0-3 percent slopes) $\frac{04}{A1M}$

This soil is on undulating upland divides, on terraces and fans of upland valleys, and on stream terraces. It formed in alluvium that is more than 5 feet deep. On the uplands abalation material consist of rock from burned-out coal beds is common on or near the surface. rocks range in size from 2 to 12 inches.

Runoff is slow and the risk from water erosion is slight, but if cultivated the risk of wind erosion is moderate. The available water holding capacity is about 10 to 12 inches for a 5-foot profile, and the permeability is moderate.

These soils are used for range, dry-farmed small grains, and irrigated farming.

9004 loam (3-8 percent slopes) $\frac{04}{B2H}$

This soil occurs in small areas on fans and ridges between the intermittent stream valleys in the uplands. Surface textures range from heavy sandy loam to loam. This surface runoff is low and the permeability is moderately high. Erosion hazard from water is low. Soil depth ranges from 6 to over 10 feet. if cultivated, wind erosion may result in moderate soil blowing.

9004 series (7-12 percent)slopes) $\frac{04}{C3N}$

This soil occurs on fans and foot slopes along intermittent natural drains in the uplands. Surface textures range from heavy sandy loams to loams. Permeability is moderately high and the hazard from water erosion is low, but damage may be caused by runoff from less permeable soils on higher slopes. Soil depth may be in excess of 18 feet. If cultivated, wind erosion may result in moderate soil blowing. This land is used for range here, and far dry and irrigated farming at other locations.

5. 9005 (Lambeth) series

This series consists of well-drained soils on tabular divides and foot slopes in the uplands. The soils have formed over very weakly consolidated silty shale and clayey shale. Slopes are from 0 to 15 percent, and elevation ranges from 3,260 to 3,120 feet. This soil is permeable and the risk of water erosion is slight except where located below steep slopes of more slowly permeable soil. Wind erosion hazard risk is moderate to high if cultivated.

The average annual precipitation is 14 and the frost-free season is 108 to 120 days. A representative profile is offered for each major slope phase found in the study area.

UNITED STATES
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OTTER CREEK STUDY SITE
OTTER CREEK COAL FIELD

SOIL SERIES DESCRIPTIONS

DRAWN. H.B.W. .... SUBMITTED ....
TRACED .... RECOMMENDED ....
CHECKED. H.B.W. .... APPROVED ....

BILLINGS, MONTANA JULY, 1975
SHEET 2 OF 5
1305-600-30

9005 series (0-2 percent slope) $\frac{60}{A1M}$

This soil has formed on weskly consalidated silty shale located on tabular divides. Typically the surface soil is a light grayish brown silt loam. The subsoil is a pale brown silt loam that grades to a heavy loam with depth and is underlain by shale at 24 to 30 inches. Discontinuous layers of lenticular hard sandstone are common on or near the surface. This soil is used for range.

Representative Profile:
Location: 1,300 feet north and 800 feet west of SE corner of Sec. 34, T. 3 S., R. 45 E.
Classification: Ustic torriorthents; fine-silty, mixed (calcareous), frigid
Slope: 2% Class: Moderately sloping Kind: Convex Aspect: West

Control section Limits - Upper:	25 cm.	Lower:	100 cm.
Site Number	4	County:	Powder River
Month Sampled:	October	Stoniness:	Class 0
Permeability:	Moderate	Elevation:	3,260 feet
Drainage Class:	Well drained	Vegetation:	Grasses, forbs, and shrubs
Physiography:	Level of undulating Uplands	Precipitation:	35.6 cm.
Parent Material:	Highly weathered Interbedded shale and siltstone		

A1 0-8 cm. (0-3 inches) — Yellowish brown (10YR5/4) crushed dry peds; brown (10YR4/3) crushed moist peds; silt loam; weak medium subangular blocky structure separating to fine granular structure; slightly hard, friable, nonsticky, nonplastic; many very fine and fine roots throughout horizon; many very fine tubular continuous pores; pH 8.0 (water 1:5); mildly effervescent (HCL); clear smooth boundary.

AC 8-20 cm (3-8 inches) -- Brown (10YR 5/3) crushed dry peds; yellowish brown (10YR5/4) crushed moist peds; silt loam; weak medium and coarse subangular blocky structure separating to granular structure; slightly hard, friable, nonsticky, nonplastic; common to many very fine and fine roots throughout horizon; many very fine tubular discontinuous pores; pH 8.1 (water 1:5); moderately effervescent (HCl); gradual wavy boundary.

C1Ca 20-24 cm. (8-17 inches) — Very pale brown (10YR7/4) crushed dry peds; yellowish brown (10YR5/6) crushed moist peds; light silt loam; weak medium and coarse angular blocky structure separating to granular structure; slightly hard, very friable, nonsticky, nonplastic; few to common very fine and fine roots throughout horizon; few to common very fine tubular discontinuous pores; pH 8.4 (water 1:5); violently effervescent (HCL); clear way boundary.

C2 42-92 cm. (17-36 inches) — Very pale brown (10YR7/4) crushed dry peds; light yellowish brown (10YR6/4) crushed moist peds; silt loam; moderate medium and coarse platy structure separating to granular structure; soft very friable, slightly sticky, slightly plastic; very fine roots between peds; present very fine pores; pH 8.3 (water 1:5); moderately effervescent (HCL): clear way boundary.

C3 92-152 cm. (36-60 inches) -- Very pale brown (10YR7/3) crushed dry peds; pale brown (10YR6/3) crushed moist peds; fine sandy loam; slightly hard, friable, nonsticky, nonplastic; very fine roots throughout horizon; pH 8.3 (water 1:5); moderately effervescent (HCl).

Remarks: Mapped Ec.-Elso W.M.L., J.M.S., W.P.V.

9005 (Lambeth) series (7-15 percent slopes) $\frac{05}{C3M}$

This soil has developed from colluvial material deposited over interbedded shale and siltstone. Depth to shale is less than 48 inches. These soils are on moderately steep slopes and are unsuited for dry farming. Resistant outcrops of sandstone occur at random and the upper slopes are easily eroded by water if the sod is broken. These soils are used for range.

Representative Profile:
Location: 900 feet north and 1,600 feet west of SE corner of Sec. 26, T. 3 S., R. 45 E.
Classification: Ustic torriorthents; fine-silty, mixed (calcareous), frigid
Slope: 12% Class: Moderately steep Kind: Convex Aspect: Northeast

Control Section Limits - Upper:	25 cm	Lower:	100 cm.
Site Number	5	County:	Powder River
Month Sampled:	October	Stoniness:	Class 0
Permeability:	Moderate	Elevation:	3,160 feet
Drainage Class:	Moderately well drained	Vegetation:	Grasses, forbs, and shrubs
Physiography:	Alluvial or colluvial fans	Precipitation:	55.6 cm.
Parent Material	Unconsolidated mineral sediments Interbedded shale and siltstone		

A1 0-8 cm. (0-3 inches) -- Pale brown (10YR6/3) crushed dry peds; brown (10YR4/3) crushed moist peds; loam; medium platy structure separating to granular structure; slightly hard, very friable, slightly sticky, slightly plastic; many very fine and fine roots throughout horizon; many very fine tubular discontinuous pores; pH 8.0 (water 1:5); noncalcareous (HCL).

C1Ca 8-25 cm. (3-10 inches) — Pale brown (10YR6/3) crushed dry peds; yellowish brown (10YR5/4) crushed moist peds; silt loam; weak to moderate medium subangular blocky structure separating to granular structure; slightly hard, very friable, slightly sticky, slightly plastic; common to many very fine and fine roots throughout horizon; many very fine and fine tubular discontinuous pores; pH 8.1 (water 1:5); violently effervescent; (HCL); clear wavy boarder.

C2 25-51 cm. (10-20 inches) -- Very pale brown (10YR7/3) crushed dry peds; yellowish brown (10YR5/4) crushed moist peds; silt loam; moderate to strong medium and coarse subangular blocky structure separating to granular structure; very friable, slightly sticky, slightly plastic; few very fine and fine roots throughout horizon; few to common very fine and fine tubular discontinuous pores; pH 8.3 (water 1:5); moderately effervescent (HCL); diffuse irregular boundary.

C3 51-112 cm. (20-44 inches) -- Very pale brown (10YR7/3) crushed dry peds; yellowish brown (10YR5/4) crushed moist peds; heavy silt loam; moderate medium and coarse subangular blocky structure separating to granular structure; slightly hard, friable, slightly sticky, slightly plastic; very fine roots throughout horizon; few very fine tubular discontinuous pores; pH 8.6 (water 1:5); moderately effervescent (HCL); clear wavy boundary.

C4 112-137 cm. (44-54 inches) -- White (5Y8/1) crushed dry peds; light gray (5Y7/2) crushed moist peds; silty clay and weakly consolidated interbedded shale and siltstone; medium and coarse platy structure; pH 8.2 (water 1:5); mildly effervescent (HCL); clear wavy boundary.

C5 137-152 cm. (54-60 inches) — White (2.5Y8/2) crushed dry peds; pale yellow (2.5Y7/4) crushed moist peds; silty clay loam and weakly consolidated interbedded shale and siltstone; medium and coarse platy structure; pH 8.1 (water 1:5); mildly effervescent (HCL).

Remarks: Mapped Mg. W.M.L., J.M.S., W.P.V.

6. The 9006 series consists of medium textured, well-drained soils that are more than 60 inches deep. These soils formed in loamy local alluvium in narrow valleys of intermittent natural drains. Surface runoff is slow except for water originating on adjacent slopes. The erosional hazard is slight except for channel erosion following torrential rains.

The vegetation is mid and short grasses interspersed locally with small areas of salt tolerant sedge especially near the point of origin and along the valley margin. Slopes are from 0-7 pereent and elevation ranges from 3,100 to 3,200 feet. The average annual precipitation is 10 to 15 inches, and the average annual soil temperature is 47 to 49° F. The frost-free season is 108 to 120 days.

Typically the surface and subsoil are light brownish gray loam or clay loam to 36 inches. The substratum ranges from silt loam to light clay.

The 9006 soils are used for range except where the valleys widen. In the wider valleys small fields of native hay are harvested.

Representative Profile:

Location from S½ Sec. 34, T. 3 S., R. 45 E., 800 feet north and 500 feet east.

A2 0-2 inches -- Light gray (10Y7/2) light loam; brown (10YR5/3) when moist; thin platy structure that breaks to weak fine granular; soft when dry, friable when moist; slightly sticky and slightly plastic when wet, noncalcareous; many fine and very fine roots throughout horizon; many fine tubular discontinuous pores; pH ($CaCl_2$ 7.5)(1-5 8.4); abrupt boundary.

B&A 2-7 inches -- Very pale brown (10YR7/3) light loam; brown (10YR5/3) when moist; hard when dry and friable when moist; prismatic structure; slightly sticky, and slightly plastic when wet; many fine and very fine roots; many fine to very fine continuous pores; pH ($CaCl_2$ 7.5)(1-5 8.4); noncalcareous; wavy boundary.

B2 7-16 inches -- Light gray (10YR7/1) light clay loam; grayish brown (10YR5/2) when moist; slight lime accumulation on peds and in very small pockets; medium prismatic structure; hard when dry and friable when moist; moderately sticky and plastic when wet; many very fine roots; common fine continuous pores; pH ($CaCl_2$ 7.8) (1-5 8.3) moderately calcareous, abrupt boundary.

C1Ca 16-36 inches -- White (10YR8/1) light silty clay loam; light yellowish brown (10YR6/4) when moist; angular blocky structure; hard when dry and slightly firm when moist; sticky and nonplastic when wet; roots diminish from many to few with depth; many fine continuous pores; pH ($CaCl_2$ 8.2)(1-5 8.5); diffuse boundary; moderately to strongly calcareous.

C2Ca 36-48 inches -- White (10YR8/1) silt loam, light yellowish brown (10YR6/4) when moist; angular blocky structure; hard when dry and friable when moist; slightly sticky and slightly plastic when wet; few very fine roots; many fine continuous pores; pH ($CaCl_2$ 8.4)(1.5 8.6); strongly calcareous.

C3Ca 48-72 inches -- Very pale brown (10YR7/3) silt loam; light yellowish brown (10YR6/4) when moist; weak massive structure; soft when dry and friable when moist; slightly sticky and slightly plastic when wet; few fine roots; many fine continuous tubular pores; pH ($CaCl_2$ 8.4)(1-5 8.6); strongly calcareous.

UNITED STATES
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OTTER CREEK STUDY SITE
OTTER CREEK COAL FIELD

SOIL SERIES DESCRIPTIONS

DRAWN H.B.W. SUBMITTED
TRACED RECOMMENDED
CHECKED H.B.W. APPROVED
BILLINGS, MONTANA JULY, 1975
SHEET 3 OF 5
1305-600-31

PLATE 23

9006 series (0-6 percent slopes) $\frac{06}{A2H}$ and $\frac{06}{B2H}$

These slightly to moderately saline well-drained soils occupy narrow flood plains and coalescing alluvial fans in valleys 100 to 300 feet wide. The surface 24-30 inches are nonsaline permeable medium textured soils. Typically, the subsoils are moderately to highly saline and moderate to slowly permeable. These recently deposited soils are derived from surrounding siltstone and shale. These soils are used for range.

7. 9007 series

The 9007 consists of medium textured soils of the uplands with moderately fine textured subsoils. These soils have formed over softly consolidated shale and finely layered saline alkali sandstone. Depth to the geologic strata ranges from 18 to more than 36 inches. These soils formed on tubular divides, foot slopes, toe slopes of knobs, and at the head of eroded natural drains. Slopes are 0 to 8 percent, and elevation ranges from 3170 to 3220 feet. The average annual precipitation is about 14 inches, and the frost-free season is 108 to 120 days.

Typically, the surface layer is a gray silt loam. The subsoil is brown and rests on clayey or sandy shale. The 9007 soils are used almost entirely as range except where associated with 9005 soils.

Representative Profile:

Location: 800 feet north and 200 feet east of S¼ corner Sec. 26, T. 3 S., R. 45 E.

A2 0-3 inches -- Very pale brown (10YR7/3) very fine sandy loam; dark brown (10YR4/3) when moist; vesicular platy structure that separates to crumb; soft when dry and frieble moist; nonsticky and slightly plastic when wet; many fine roots; many fine discontinuous pores; pH ($CaCl_2$ 6.6)(1-5 6.6); noncalcareous; wavy boundary.

B&A 3-8 inches -- Light yellowish brown (10YR6/4) loam; dark yellowish brown when moist; strong fine blocky breaking to medium granular; hard when dry and very firm when moist; slightly sticky and slightly plastic when wet; many medium and fine roots; many fine discontinuous pores; pH ($CaCl_2$ 6.6)(1-5 7.0); noncalcareous; clear wavy boundary.

B3t 8-16 inches -- Brown (10YR5/3) light silty clay loam; dark brown (10YR4/3) when moist; strong medium columnar structures; very hard when dry, and very firm when moist; very sticky and very plastic when wet; many medium roots along cleavage planes and fine roots through peds; few very fine discontinuous pores; pH ($CaCl_2$ 7.0) (1-5 7.3); noncalcareous; gradual boundary.

C1 16-27 inches -- Pale brown (10YR4/3); medium and fine blocky structure; very hard when dry, and very firm when moist; sticky and plastic when wet; many to few fine roots; few discontinuous fine pores; noncalcareous; pH ($CaCl_2$ 7.9)(1-5 8.2); diffuse boundary.

C2Ca 27-36 inches -- White (2.5y 8/2) silty clay loam; light gray when moist; weak massive structure; soft when dry friable when moist; plastic and sticky when wet; pH ($CaCl_2$ 8.3)(1-5 8.3); clear wavy boundary.

C3Ca 26-64 inches -- Yellow (2.5y 7/8) clay loam; light olive brown when moist; horizontal layering (silty shale); sticky and plastic when wet; pH ($CaCl_2$ 8.2)(1-5 8.4).

9007 series (0-3 percent slopes) $\frac{07}{A1N}$

This soil occurs on tabular divides and is underlain by silty shale below 40 inches. This is used almost entirely for range and may have 10 to 20 percent slick spots. Many slick spots are undergoing a change and are beginning to revegetate. The salinity and sodicity level is quite variable and may occur within 2 inches of the surface. Generally, outside the slick spots the soils are nonsaline and nonalkaline to 30 inches.

9007 Series (3-7 percent slopes) $\frac{07}{B2N}$

This soil occupy rounded slopes and weak ridges near the upper limits of intermittent drains. They are underlain by saline alkali gray silty shale at about 24 inches or sandstone where eroded slick spots become dominant. The well-drained slopes have a profile with a typical upper control section and slick spots are not common. Infiltration is moderate and erosion is slight. On the well-drained slopes this soil supports a good stand of mixed grasses and is used largely for range.

8. 9008 series

This series consists of well-drained to excessively drained medium textured soils that formed on weakly consolidated sandstone and coarse siltstone that has been baked by the burning of major coal beds. The native vegetation consists of needle and thread, blue grama, and slender wheat grass. Cheatgrass was the principal forb recorded. Silver sage is common but not in continuous stands. These soils occupy smooth tubular divides in burned-out coal areas.

Slopes are from 0 to 7 percent and elevation is about 3,150 to 3,200 feet. The average annual precipitation is 14 inches and the frost-free season is 108 to 120 days. Ringling-Cabba soils join these soils in areas with bake rock substrata and 9003 and 9002 soils represent the areas with unbaked rock substrata.

Typically, the surface layer is fine sandy loam about 16 inches thick. Weakly consolidated sandstone is less than 30 inches below the surface and grades into loose sand below this depth. The entire profile exhibits the reddish brown and pinkish color associated with burn areas.

Representative Profile:

Location: 1,200 feet south and 1,050 feet east of NW corner Sec. 34, T. 3 S., R. 45 E.

A1 0-2 inches — Light reddish brown (5YR6/3) fine sandy loam, reddish brown (5YR4/3) when moist; fine crumb structure; soft when dry and very friable when moist; nonsticky and nonplastic when wet; many very fine and fine roots; many fine and very fine tubular continuous pores; pH ($CaCl_2$ 6.8)(1-5 8.2); clear wavy boundary.

AC 2-16 inches -- Light reddish brown (5YR6/3) fine sandy loam, reddish brown (5YR4/4) when moist; weak medium prismatic structure separating to fine and medium granular; soft when dry and very friable when moist; nonsticky and nonplastic when wet; many fine and very fine continuous tubular pores; pH ($CaCl_2$ 6.8) (1-5 8.3); diffuse boundary.

C1 16-25 inches -- Pink (7.5YR7/4) fine sandy loam, pinkish gray (7.5YR6/2) when moist; weak subangular blocky structure; soft when dry and friable when moist; nonsticky and nonplastic when wet; many fine and very fine roots; many fine and very fine continuous pores; pH ($CaCl_2$ 7.4)(1-5 8.1); abrupt boundary.

C2 25-31 inches -- Pink (7.5YR8/4) fine sandy loam; pinkish gray (7.5YR7/3) when moist; weakly consolidated sandstone with coarse (platy) layers that separate easily to loose structure; slightly hard when dry and friable when moist; few fine roots; pH($CaCl_2$ 7.9) (1-5 8.4); gradual boundary.

C3 31-72 inches -- Light red (10R6/8) sand, light red (10R6/6) when moist; weakly consolidated sandstone with medium (Platy) layers that separate to loose structure; soft when dry and friable when wet; few fine roots in upper part of horizon; pH ($CaCl_2$ 8.2)(1-5 8.7)

C4 72-102 inches -- Light red (10R6/8) sand, light red (10R6/6) when moist; weakly consolidated sandstone with medium and fine layers that separate easily to loose structure. The interbedded layers include white (10YR8/2) and reddish yellow (5YR8/2); soft when dry and frieble when moist; nonsticky and nonplastic when wet; pH ($CaCl_2$ 8.2)(1-5 8.9). This profile was core sampled with a hydraulic push-tube core machine.

9008 series (0-7 percent slope) $\frac{08}{A1M}$ $\frac{08}{B1M}$

These soils occur in tubular divides and the low gradient upper slopes which are often adjacent to steep scarps. The substrata varies from weakly consolidated sandstone to baked silt and claystone.

This soil has slow runoff and high permeability. The available water capacity is 8 to 10 inches for a 5 foot depth. The organic matter in the surface is moderate and plant roots penetrate the soil readily.

Although, most 9008 soils are in native grasses, they are well suited for irrigation farming or will produce well if dry farmed. Dry-farmed areas could be moderately susceptible to wind erosion. These two phases are suitable for borrow material to be used in reclamation plans.

Other 9008 soil phases were mapped when they joined the area with strippable coal. These miscellaneous phases $\frac{08}{E3N}$, $\frac{08}{F3N}$, and $\frac{08}{B2M}$ were largely outside the study area and were not tabulated. Topographically these mapping units are generally unsuited for borrow areas and the parent material is very shallow.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

OTTER CREEK STUDY SITE
OTTER CREEK COAL FIELD

SOIL SERIES DESCRIPTIONS

DRAWN H.B.W. .... SUBMITTED
TRACED .... RECOMMENDED
CHECKED H.B.W. .... APPROVED
BILLINGS, MONTANA JULY, 1975
SHEET 4 OF 5
1305-600-32

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PLATE 24

9. 9009 series

The 9009 series consists of well drained medium textured soils that are usually more than 40 inches deep over soft shale. The native vegetation is mid and short grasses. Elevation ranges from 3,100 to 3,200 feet. The average annual precipitation is 14 inches and the frost-free season is from 108 to 120 days. These soils are associated with 9003, 9003S, and 9006 soils.

Typically, the surface layer is light grayish brown silt loam or fine sandy loam about 4 inches thick. The subsoil, a light gray fine sandy loam or silt loam, is saline and/or sodic. Shale beds are at a depth of 36 inches to more than 10 feet.

The 9009 series are used mostly for range.

Representative Profile:

Location from center of Sec. 2, T. 4 S., R. 45 E., 450 feet north and 400 feet east.

A1 0-2 inches -- light gray (2.5Y 7/3) loam, light grayish brown (2.5Y6/3) when moist; fine granular structure; sofr when dry, friable when moist; slightly sticky and slightly plastic when wet; highly calcareous many fine roots and discontinuous tubular pores; pH(CaCl$_2$ 7.6)(1-5 8.5) boundary diffuse.

AC 2-14 inches -- light gray (2.5Y7/3) loam, light grayish brown (2.5Y7/4) when moist; medium granular structure; sofr when dry, friable when moist; slightly sticky and slightly plastic when wet; highly calcareous; many fine roots and discontinuous tubular pores; clear boundary; pH(CaCl$_2$ 7.6)(8.5).

C1Ca 14-28 inches -- pale yellow (2.5Y8/4) fine sandy loam, pale yellow (2.5Y7/4) when moist; fragmental to weak massive structure hard when dry, friable when moist; many fine roots and tubular discontinuous pores; nonsticky and nonplastic when wet; highly calcareous; abrupt boundary; pH(CaCl$_2$ 8.2)(1-5 9.2).

C2Ca 28-44 inches — light gray (10YR7/2) fine sandy loam, pale brown (10YR6/3) when moist; weak massive structure; slightly hard when dry, friable when moist; nonsticky and nonplastic when wet; highly calcareous; many to common fine roots; few fine continuous pores; pH(CaCl$_2$ 8.3)(1-5 9.2).

C3Ca 44-52 inches -- light gray (10YR7/2) very fine sandy loam, pale brown (10YR6/3) when moist; weak massive structure; slightly hard when dry, frisble when moist; common to few fine roots;

9009 series (0-3 percent slopes) $\frac{09}{A1M}$

These soils occupy lower foot slope between intermittent drains and along recent alluvial deposits. They have formed on medium textured deposits eroded from local silty shales. The subsoil is quite saline and often may be moderately to highly alkaline. The organic matter content and fertility is low. Plant roots penetrate the upper profile readily but few roots are found in the highly saline lower horizons.

Most of this soil is in native grasses. Some areas are irrigateo but salinity and deep can become series problems.

9009 series (3-7 percent slope) $\frac{09}{B2M}$

These soils occupy foot slopes below moderately to highly erosive 9003 soils with numerous shale exposures. They are very similar to the $\frac{09}{A1M}$ soils except for slope and erosion.

10. 9010 series.

The 9010 series consits of well-drained calcareous soils on stream terraces, fans and foot slopes of the uplands. These moderately fine loamy textured soils occupy 0 to 8 percent slopes at elevation ranging from 3,100 to 3,140 feet. The average annual precipitation is 14 inches; the annual soil temperature is 47 to 49 degrees F., and the frost-free season is 108 to 120 days. These soils are associated with the 9003, 9001, and 9004 series.

Typically, the surface layer is light gray clay loam or silty clay loam about 10 inches thick. The subsoil is a pale brown silty clay loam. Below 36 inches the soil is moderately aaline .

These soils are used for dryland hay meadows and range.

Representative Profile:

Location: 480 feet north and 760 feet west of SE corner of Sec. 2, T. 4 S., R. 45 E.

A1 0-2 inches -- light gray (10YR7/2) clay loam, pale brown (10YR6/3) when moist; fine granular structure; soft when dry, friable when moist; moderately sticky and moderately plastic when wet; noncalcareous; many medium and fine roots; many fine discontinuous pores; clear wavy boundary; pH(CaCl$_2$7.7)(1-5 8.4).

B2 2-12 inches — pale brown (10YR6/3) clay loam, brown (10YR6/3) when moist; medium prismatic structure; hard when dry, firm when moist; sticky and plastic when wet; many fine and very fine roots; many fine continuous pores; noncalcareous; pH(CaCl$_2$7.7) (1-5 8.4); abrupt boundary.

C1Ca 12-36 inches -- light gray (10YR7/1) clay loam, grayish brown (10YR5/2) when moist; prismatic structure separating to medium and fine granular; slightly hard when dry, friable when moist; sticky and plastic when wet; many to few fine roots; common tubular discontinuous pores; strongly calcareous; pH(CaCl$_2$ 7.7)(1-5 8.4); diffuse boundary.

C2Ca 36-60 very pale brown (10YR8/3) silty clay loam; pale brown (10YR6/3) when moist; coarse angular blocky structure; slightly hard when dry; firm when moist; sticky and plastic when wet; few roots; common fine continuous tubular pores; strongly calcareous; (CaCl$_2$7.9)(1-5 8.6) gradual boundary.

C3Ca 60-72 -- Very pale brown (10YR8/3) silty clay loam; very pale brown (10YR7/4) when moist; massive structure; hard when dry, very firm when moist; sticky and plastic when wet; few fine discontinuous tubular pores; pH(CaCl$_2$8.0)(1-5 8.4); cbrupt boundary.

C4Ca 72-110 inches -- Very pale brown (10YR8/3) silty clay; pale brown (10YR6/3) when moist; medium angular blocky structure hard when dry, very firm moist; very sticky and plastic when wet; few pores; slightly calcareous; pH(CaCl$_2$8.2)(1-5 8.3). Sampled with a hydraulic core machine.

9010 Series (3-7 percent slope) $\frac{010}{B2N}$

This soil is on foot slopes and creek terraces and is underlain by shale at a depth of more than 5 feet, This soil has moderate runoff and permeability. The available water capacity is 9 to 11 inches for a 5 foot profile. If cultivated the soil would be susceptible to soil blowing and water erosion.

This soil is used for ronge and native hay meadows.

9010 Series (12-20 percent slopes) $\frac{010}{04N}$

This soil occupies the lower foot slopes and terrace scarps along alluvial valleys. it is quite similar to $\frac{010}{B2N}$ except it is more severely eroded and may include cutbank erosion locally. Where the "B" horizon is exposed the plant population is reduced. This soil may be subject to moderate to severe water erosion. It is used for range and native hay meadows.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

OTTER CREEK STUDY SITE
OTTER CREEK COAL FIELD

SOIL SERIES DESCRIPTIONS

DRAWN. H.B.W. .... SUBMITTED ....
TRACED .... RECOMMENDED ....
CHECKED. H.B.W. .... APPROVED Phil Q. ....
BILLINGS, MONTANA JULY, 1975
SHEET 5 OF 5
1305-600-33

PLATE 25

SEC. 34 - T. 3 S., R. 45 E

SEC. 26 - T. 3 S., R. 45 E

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
OTTER CREEK STUDY SITE
OTTER CREEK COAL FIELD

SOIL LABORATORY RESULTS

SECTIONS 26 & 34, - T. 3 S., R 45 E.

LAND CLASSIFICATION H.B.W.
SUBMITTED H.B. Ward
DRAWN E.G.M.
RECOMMENDED
CHECKED H.B.W.
APPROVED C. Q. Gille

BILLINGS, MONTANA
MARCH 1975
1305-600-27

SEC. 2-T. 4 S., R. 45 E.

MISSOURI SOURIS PROJECTS OFFICE
BUREAU OF RECLAMATION
BISMARCK, NORTH DAKOTA
SOIL ANALYSIS DATA SHEET

Date Received 8/6/74
Date Reported 9/1/74

AREA: Otter Creek [illegible] INVESTIGATOR: [illegible] SECTION: 2 TOWNSHIP: 4S RANGE: 45E

Lab Number	Boring Number	Depth in Inches	Field Texture	% Sand	% Silt	% 2µ Clay	Lab Texture	1/10 Bar Tension	15 Bar Tension	in/hr	in/hr	in/hr	Bu Vol	EC ×10³	pH 1:5	pH Paste	ECe ×10³	Na meq/l	Ca+Mg meq/l	SAR						P Avail ppm/soil	
W-93	1	0-8	SiC						14.9	0.34	0.32		36	<0.16	8.0	7.5									—		
94		8-13	SiCL						12.9	0.32	0.26		22	0.26	8.1	7.7									—		
95		13-23	SiCL						13.7	0.10	0.12		23	2.1	7.9	7.7	4.0								—		
96		23-40	SiCL						13.4	0.03	0.05		25	1.9	7.9	7.8	10.								—		
97		40-54	SiL						12.6	0.10	0.10		26	1.3	8.0	7.9	8.8	58	64	10	5.33				—		
98		54-60	[illegible]						14.7	0.04	0.03		34	0.82	8.3	8.0	5.1								—		
W-99	2	0-4	[illegible]						11.0	0.40	0.32		22	<0.16	7.7	7.4									—		
100		4-18	SiCL						10.1	0.42	0.84		25	0.16	8.8	8.4									—		
101		18-36	HSiCL						18.9	0.00	0.00		100	0.42	9.2	8.5	1.9								—		
102		36-54	HSiCL						18.9	0.00	0.00		100	0.60	9.5	8.5 8.8	2.3	22	2.4	20		2.89			—		
103		54-64	SiCL						13.6	0.00	0.00		85	0.70	9.3	8.5	3.0								—		
W-104	3	0-18	SiCL						11.1	0.22	0.26		22	<0.16	8.3	7.7									—		
105		18-30	SiCL						10.3	0.04	0.07		21	0.82	8.8	8.2	6.1								—	66	
106		30-56	SiCL						12.1	0.22	0.26		21	0.29	8.3	8.2									—	55	
107		56-72	SiL						5.7	0.04	0.03		21	1.6	8.3	8.1	13	113	90	17	5.05				—		
108		72-102	SiCL						13.1	0.07	0.07		34	2.0	8.1	7.9	15								—		
W-116	4	0-8	SiL						3.5	1.52	1.80		19	<0.16	8.1	7.4							5.9	4.9		—	
117		8-24	[illegible]						8.1	0.00	0.04		20	<0.16	8.5	7.8							1.9	2.0		—	
118		24-36	CL						8.1	0.52	0.52		18	<0.16	8.7	7.9										—	4.5
119		36-62	[illegible]						[illegible]	0.64	0.69		19	<0.16	9.0	8.0										—	
120		62-93	[illegible]						6.1	0.76	0.80		18	0.45	8.8	8.0	3.6									—	
121		93-114	[illegible]						8.7	0.48	0.52		19	2.0	8.8	7.9	2.9									—	6.0
W-126	5	0-14	[illegible]						8.9	0.74	1.00		18	<0.16	8.5	7.7										—	
127		14-32	[illegible]						7.1	0.36	0.36		18	<0.16	8.7	7.9										—	8.6
128		32-60	[illegible]						6.5	0.60	0.60		17	<0.16	8.9	8.1										—	
129		60-87	VFSL						7.7	0.80	0.80		18	<0.16	8.8	8.2										—	9.0
130		87-102	VFSL						[illegible]	0.88	0.88		17	<0.16	9.0	8.2										—	
131		102-120	VFSL						7.1	0.64	0.66		16	<0.16	8.9	8.2										—	3.5
W-132	6	0-6	[illegible]						10.6	1.00	1.56		21	<0.16	8.4	7.7							1.9	4.0	3	—	
133		6-22	SiL						10.3	0.52	0.52		21	<0.16	8.6	7.9										—	
134		22-40	SiCL						9.1	0.28	0.20		20	<0.16	9.1	8.1										VW	2.8
135		40-64	SiCL						9.6	0.10	0.10		20	0.44	9.2	8.2	3.2						1.9	3.3	3	—	
136		64-86	SiCL						9.7	0.08	0.05		21	0.80	9.0	8.2	6.6						2.6	7.0	11	[illegible]	
W-137	7	0-6	[illegible]						14.1	0.64	0.64		24	<0.16	8.4	7.7										—	
138		6-32	[illegible]						14.0	0.00	0.40		23	<0.16	8.5	7.8										—	5.6
139		[illegible]	[illegible]						14.7	0.03	0.04		29	.21	9.1	8.1	1.9						2.3	12.8	10	VW	
140		[illegible]	SiC						14.8	0.00	0.02		30	1.10	8.7	8.2	6.7	54	29	14						—	4.0
141		60-90	[illegible]						9.9	0.18	0.02		23	1.35	8.7	8.2	9.0									—	
142		90-130	[illegible]						10.0	0.24	0.24		18	<0.16	8.4	8.1										—	
W-143	8	[illegible]	L						9.1	1.20	1.28		19	<0.16	8.4	7.7										—	
144		9-16	[illegible]						10.7	0.68	0.64		20	<0.16	8.6	7.9										—	
145		16-40	SiCL						10.4	0.14	0.14		23	.18	9.3	8.1 8.2	0.81	8.4	2.5	7.5		0.80				—	
146		[illegible]	FSL						7.2	0.26	0.26		25	.45	9.3	8.2	3.0									—	
W-147	9	0-12	[illegible]						13.0	0.40	0.34		21	<0.16	8.4	7.7										—	
148		12-36	[illegible]						14.7	0.24	0.20		23	.20	8.6	7.9										—	5.4
149		36-50	[illegible]						14.2	0.00	0.32		22	1.1	8.4	8.0	7.0	36	61	6.6						—	7.5
150		[illegible]	[illegible]						13.2	0.00	0.04		22	1.1	8.6	8.1	7.5						9.2	29.9	27	—	
151		[illegible]	[illegible]						15.1	0.05	0.07		27	1.2	8.6	8.2	8.1									—	
W-152	10	0-12	FSL						8.3	0.84	0.80		20	<0.16	8.5	7.7										—	
153		12-33	FSL						6.9	0.64	0.64		18	<0.16	8.7	7.7										—	8.5
154		33-51	[illegible]						6.5	0.68	0.60		19	.21	8.5	7.9										—	
155		[illegible]	[illegible]						10.9	0.24	0.16		21	.45	8.4	7.9	3.1									—	10.8
156		[illegible]	[illegible]						7.1	1.72	2.12		20	.80	8.7	8.1	7.3						6.8	7.0	5	—	
W-157	11	[illegible]	[illegible]						14.9	0.96	1.76		27	<0.16	7.7	7.0										—	
158		[illegible]	[illegible]						11.7	0.60	0.66		21	<0.16	7.6	7.1										—	
159		8-22	[illegible]						10.1	0.30	0.32		22	<0.16	8.1	7.4										—	
160		22-30	[illegible]						10.5	0.44	0.30		21	<0.16	8.2	7.6										—	
161		30-44	[illegible]						8.2	0.08	0.52		19	<0.16	8.5											—	
162		[illegible]	[illegible]						7.7	0.44	0.40		18	<0.16	8.5	7.8										—	
163		[illegible]	[illegible]						9.9	0.29	0.28		19	<0.16	8.7	8.0										—	
W-164	12	[illegible]	[illegible]						14.8	0.26	0.28		27	0.16	8.6	7.8										—	
165		12-30	[illegible]						12.9	0.72	0.72		21	1.1	8.3	8.0	7.0	49	44	10	22.33					—	
166		[illegible]	[illegible]						15.4	0.12	0.12		24	2.5	8.6	8.3	17									—	
167		[illegible]	[illegible]						16.3	0.06	0.06		27	3.0	8.5	8.3	15									—	8.0
W-168	13	0-7	[illegible]						10.4	0.76	0.64		20	<0.16	8.4	7.5										—	
169		7-16	[illegible]						11.7	0.52	0.56		21	3.4	8.3	8.3	0.42	1.3	3.8	0.9	17.50					—	
170		[illegible]	[illegible]						10.2	0.00	0.04		20	0.92	8.5	8.2	8.8									—	
171		[illegible]	[illegible]						10.5	0.40	0.38		20	1.5	8.6	8.4	12									—	
172		[illegible]	[illegible]						9.9	0.72	0.76		20	1.5	8.6	8.4	12									—	13.7
173		[illegible]	[illegible]						9.5	0.92	1.04		20	1.7	8.6	8.5	11									VW	
174		[illegible]	[illegible]						8.8	1.52	1.92		18	1.5	8.5	8.2	9.3						9.8	28.6	26	VW	10.1
175		[illegible]	[illegible]						10.4	0.04	0.44		21	0.9	8.5		8.4						1.7	6.6	5	—	
W-176	[illegible]	[illegible]	[illegible]						15.1	1.80	2.16		23	<0.16	8.5	7.7							10.4	16.9	18	—	
177		8-18	[illegible]						16.3	0.32	0.30		60	<0.16	8.5	7.8										—	
178		18-29	[illegible]						16.0	0.12	0.12		35	<0.16	8.4	8.0										—	
179		[illegible]	[illegible]						15.9	0.05	0.06		36	<0.16	8.6	8.0	0.61	2.6	3.8	1.9						—	
180		39-43	[illegible]						20.3	TR	[illegible]		39	0.20	8.6	8.0										—	
W-230	15	[illegible]	[illegible]						11.3	0.64	0.76		22	<0.16	7.9										—		
231		16-36	CL						9.9	0.32	0.48		22	<0.16	8.6										—		
232		36-64	CL						9.1	0.08	0.07		28	1.30	8.1		11.0								—		
W-233	16	0-12	[illegible]						13.1	0.12	0.14		23	<0.16	8.5										—		
234		12-18	CL						12.8	[illegible]	0.08		25	0.71	8.3										—		
235		[illegible]	[illegible]						13.8	[illegible]	0.10		23	1.32	8.0		12.4	96	110	13	10.9				—		
236		[illegible]	[illegible]						12.9	[illegible]	0.08		23	1.70	8.2		11.0								—	4.5	
237		[illegible]	[illegible]						13.9	[illegible]	0.44		25	1.15	8.2		10.0								—		
238	16a		[illegible]						14.8	0.05	0.04		24	0.81	[illegible]		7.0								—		
239	16b		SiCL						13.8	[illegible]	0.34		22	0.70	8.1		6.0								—		
240	16c		[illegible]						14.3	[illegible]	0.10		26	0.19	8.7										—		
241	16d		CL						13.8	[illegible]	0.04		27	0.62	8.1		6.6								—		
W-313	18	0-8	CL						13.9	[illegible]	0.22		23	<0.16	7.0										—		
314		8-30	CL						10.8	[illegible]	0.04		21	<0.16	7.8										—	7.4	
315		30-54	CL						7.8	0.14	0.14		18	<0.16	[illegible]										—		
316		[illegible]	[illegible]						10.6	[illegible]	0.16		20	<0.16	8.5										—	10.3	
317		[illegible]	[illegible]						7.9	[illegible]	1.04		19	[illegible]	8.4										—		
318		[illegible]	[illegible]						11.2	[illegible]	0.38		20	<0.16	8.5										—	7.2	
W-311	~~19~~	0-9	CL						16.8	1.80	3.52		23	<0.16	8.0										VW		
312		9-24	[illegible]						15.6	[illegible]	0.48		25	<0.16	8.4										—		

DRILL CORE

MISSOURI SOURIS PROJECTS OFFICE
BUREAU OF RECLAMATION
BISMARCK, NORTH DAKOTA
SOIL ANALYSIS DATA SHEET

Geology Drill Cores
AREA: Otter Creek Montana INVESTIGATOR: H DuPree SECTION: TOWNSHIP: RANGE:

7/24/74 + 8/2/74
Date Received (1-7) (8-10)
Date Reported 9/10/74

Lab Number	Drill Hole Number	Depth in Feet	Field Texture	% Sand	% Silt	% 2µ Clay	Lab Texture	1/10 Bar Tension	15 Bar Tension	in/hr	in/hr	in/hr	Bu Vol	EC ×10³	pH 1:5	pH Paste	ECe ×10³	Na meq/l	Ca+Mg meq/l	SAR						P Avail ppm/soil
G-1	74-101	[illegible]-5.6							5.7	[illegible]	0.07		26	.89	8.7	8.2	7.1								—	
2		19.4-21.2							11.5	[illegible]	TR		47	.57	8.9	8.3	5.2								—	11.0
3		[illegible]							18.2	0.00	0.00		78	.49	8.3	7.6	[illegible]								—	9.5
4		47.1-52.0							14.5	0.50	0.00		97	.45	9.1	8.2	4.2								—	9.5
5		[illegible]							35.5	0.00	0.00		119	.41	9.3	8.3	2.9								—	7.5
6		[illegible]							6.9	[illegible]	[illegible]		125	.36	9.4	8.2	3.1	27	2.4	25		2.40			—	9.5
7		[illegible]-155.0							12.1	0.00	0.00		110	[illegible]	9.1	8.0									—	6.5
8		[illegible]							1.9	0.20	0.20		16	.30	8.9	8.0									—	8.5
9		[illegible]-190.6							2.5	0.00	0.20		31	.40	8.7	7.9	4.5								—	9.0
10		264-[illegible]							2.4	0.20	0.20		16	.22	8.5	7.9									—	15.0
G-11	74-102	1.5-7.6							6.0	0.06	0.07		22	<0.16	8.4	7.7									—	
12		7.6-16.0							10.3	[illegible]	0.16		27	<0.16	8.2	7.7									—	[illegible]
13		18.0-23.5							11.9	0.05	0.06		34	<0.16	8.2	7.7									—	2.1
14		[illegible]-41.5							[illegible]	[illegible]	0.24		16	<0.16	8.1	7.8									—	3.8
15		[illegible]-67.5							2.1	[illegible]	0.72		16	<0.16	8.8	7.6									—	2.8
16		67.5-84.5							2.1	0.40	0.40		16	<0.16	8.7	7.8									—	3.5
17		94.0-102.0							6.4	0.06	0.08		21	<0.16	[illegible]	7.7									—	
18		102.0-110.0							9.3	[illegible]	0.24		23	<0.16	[illegible]	7.6									M	9.0
19		111.0-[illegible]							6.9	0.04	0.06		22	<0.16	8.2	7.5									M	10.0
20		[illegible]-200.0							6.8	0.03	0.04		21	<0.16	8.5	7.6									M	9.5
21		[illegible]							2.6	0.36	0.38		16	0.21	7.5										M	
G-22	74-103	[illegible]-8.5							18.7	[illegible]	TR		34	1.40	7.8		[illegible]								—	11.3
23		8.5-13.5							13.8	0.24	0.34		25	1.90	6.1		13								—	
24		13.5-22.0							3.0	0.04	0.04		23	[illegible]	9.0		4.5								M	9.5
25		22.0-[illegible]							7.2	0.07	0.06		29	0.61	[illegible]		5.1								M	7.6
26		35.0-40.0							7.6	0.04	0.07		29	0.41	8.6		7.0								—	6.5
27		40.0-42.0							6.2	[illegible]	1.96		19	0.35	8.1										M	11.3
28		50.1-58.3							6.1	[illegible]	TR		30	[illegible]	8.5										W	
29		[illegible]-64.4							4.6	[illegible]	TR		26	[illegible]	[illegible]		2.6	26	10.1	12					—	6.4
30		[illegible]							10.1	[illegible]	0.04		31	0.35	[illegible]										M	
31		[illegible]							2.6	0.10	0.10		11	[illegible]	[illegible]										[illegible]	
32		[illegible]							8.2	0.06	0.10		29	[illegible]	[illegible]										M	9.0
33		[illegible]							3.6	0.10	0.10		18	[illegible]	9.7										[illegible]	
34		[illegible]							5.3	0.06	0.08		26	<0.16	8.5										[illegible]	8.0
35		[illegible]							9.5	0.10	0.14		30	[illegible]	8.4										—	7.2
36		[illegible]							4.7	0.06	0.10		21	[illegible]	8.4										—	
37		[illegible]							4.9	0.00	TR		30	[illegible]	[illegible]										M	
38		[illegible]-221.0							3.6	0.04	0.04		19	[illegible]	[illegible]										M	
G-39	74-104	[illegible]							7.7	0.04	0.04		25	[illegible]	9.0		1.3	3.5	6.3	2.0					M	9.5
40		[illegible]							10.1	0.22	0.22		34	[illegible]	[illegible]										W	8.9
41		[illegible]							12.7	[illegible]	0.30		37	[illegible]	[illegible]										W	6.2
42		[illegible]-44.9							10.5	[illegible]	[illegible]		22	[illegible]	[illegible]										M	2.6
43		[illegible]-51.1							4.9	0.20	2.22		18	[illegible]	8.9										—	13.4
44		[illegible]							1.9	0.60	0.68		15	[illegible]	9.0										—	6.0
45		[illegible]							1.8	0.90	1.08		14	[illegible]	9.1		0.71	3.9	3.6	2.9					—	
46		[illegible]							2.0	0.56	0.64		14	[illegible]	[illegible]										—	8.5
47		[illegible]							2.3	0.44	0.44		14	[illegible]	9.0										--	
48		[illegible]							6.7	0.10	0.10		21	[illegible]	[illegible]										—	5.7
49		[illegible]							5.7	0.16	0.14		24	[illegible]	[illegible]										—	
50		[illegible]							9.6	0.12	0.22		25	[illegible]	[illegible]										M	5.2
51		[illegible]							10.3	0.20	0.64		25	[illegible]	[illegible]										M	
52		[illegible]-200.0							6.6	0.02	0.04		23	[illegible]	[illegible]										—	6.2
53		[illegible]-213.7							[illegible]	0.52	0.64		11	[illegible]	[illegible]										M	
54		213.7-[illegible]							10.9	0.04	0.04		32	[illegible]	8.7										M	
G-55	74-105	0.0-8.6							17.9	[illegible]	0.06		24	[illegible]	[illegible]		11								—	8.6
56		[illegible]							9.0	[illegible]	0.07		[illegible]	[illegible]	[illegible]										—	12.0
57		[illegible]							5.2	0.06	0.06		20	[illegible]	[illegible]										—	6.5
58		[illegible]-34.3							2.0	0.60	[illegible]		16	[illegible]	8.2										—	5.3
59		36.3-44.0							8.0	0.12	1.84		21	[illegible]	8.4										VW	8.1
60		[illegible]							15.3	0.44	1.04		27	0.51	6.3		[illegible]								M	8.1
61		[illegible]-52.8							14.9	0.00	[illegible]		30	0.50	7.5										W	10.0
62		[illegible]							19.6	0.00	[illegible]		35	[illegible]	7.1		[illegible]								W	
63		[illegible]							12.1	0.00	[illegible]		58	[illegible]	8.5										VW	13.0
64		[illegible]							10.4	0.06	[illegible]		48	0.30	[illegible]										VW	
65		[illegible]							24.5	0.06	[illegible]		[illegible]	0.30	7.7										M	
66		[illegible]							27.1	0.00	[illegible]		[illegible]	0.31	[illegible]		1.3	20	[illegible]	28					VW	12.7
67		[illegible]							25.2	0.00	[illegible]		75	[illegible]	8.5										VW	
68		[illegible]-120.0							23.3	0.00	[illegible]		95	[illegible]	8.8										VW	8.7
69		[illegible]							12.3	0.03	[illegible]		55	0.19	8.7										VW	
70		[illegible]							31.0	[illegible]	[illegible]		110	[illegible]	8.5										VW	8.6
71		[illegible]							11.6	0.40	[illegible]		80	0.20	8.7		1.3	15	0.6	27					VW	
72		[illegible]-177.0							7.4	0.00	[illegible]		110	[illegible]	9.1										VW	12.6
73		[illegible]							26.1	0.50	[illegible]		125	0.23	9.2										VW	
74		[illegible]							10.7	[illegible]	[illegible]		80	<0.16	8.5										VW	10.2
75		[illegible]-200.0							12.9	0.00	[illegible]		100	<0.16	[illegible]										VW	
76		[illegible]							7.2	0.06	0.07		19	<0.16	8.5										W	
G-77	74-106	1.0-20							[illegible]	[illegible]	[illegible]		18	0.34	8.4										[illegible]	
78		[illegible]-30.5							10.9	0.08	0.07		27	0.79	8.2		2.5								—	6.8
79		[illegible]-52.5							7.1	0.06	0.03		31	[illegible]	[illegible]										—	5.6
80		[illegible]							13.7	0.00	0.02		33	0.18	[illegible]										—	6.4
81		[illegible]							10.4	0.00	[illegible]		35	[illegible]	[illegible]										—	
82		[illegible]							11.1	0.00	[illegible]		67	<0.16	[illegible]										VW	6.4
83		[illegible]							13.2	0.00	[illegible]		90	0.20	[illegible]										M	
84		[illegible]							[illegible]	0.00	[illegible]		50	0.23	8.6		1.3	14	0.7	24					—	7.7
85		[illegible]							14.9	[illegible]	[illegible]		60	0.23	[illegible]										VW	
86		[illegible]							17.2	0.00	[illegible]		120	0.28	[illegible]										VW	8.0
87		[illegible]							9.0	0.00	[illegible]		[illegible]	<0.16	[illegible]										VW	
88		[illegible]							6.3	0.06	[illegible]		79	<0.16	[illegible]										VW	
89		[illegible]								0.00	0.00		60	0.20	5.8										VW	
90		[illegible]								0.02	0.02		23	0.23	[illegible]										M	
91		[illegible]								0.14	0.16		17	0.20	8.7										VW	
G-92	74-107	[illegible]								0.04	0.04		23	[illegible]	8.3		4.8								—	
93		[illegible]-15.0								0.00	0.00		69	0.61	8.5		3.9								VW	
94		[illegible]-24.6								0.00	0.00		46	0.51	8.7		3.0								—	
95		[illegible]								0.00	0.00		63	0.61	8.7		11.0								VW	
96		49.3-50.8								0.00	0.00		190	0.31	7.7										W	

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
OTTER CREEK STUDY SITE
OTTER CREEK COAL FIELD

SOIL LABORATORY RESULTS

SECTION 2, T. 4 S., R. 4 E. AND DRILL CORE

LAND CLASSIFICATION H.B.W. SUBMITTED [illegible]
DRAWN E.G.H. RECOMMENDED [illegible]
CHECKED H.B.W. APPROVED R.Q. [illegible]
BILLINGS, MONTANA MARCH 1975 1305-600-28

Cabba Series

The Cabba series consists of well-drained, medium-textured soils that are less than 20 inches deep over softly consolidated shale. These soils formed on uplands under mid and short grasses. Slopes are 15 to 50 percent, and elevation ranges from 4,000 to 4,500 feet. The annual precipitation is 15 to 19 inches, the average annual soil temperature is 45 to 47° F., and the frost-free season is about 100 days. The Cabba soils are associated with Midway, Barvon, Campspass, Farland, and Pelan soils.

Typically the surface layer is grayish-brown silt loam about 7 inches thick. The subsoil, which extends to a depth of 16 inches, is light-gray silt loam and loam that is strongly calcareous. It is underlain by stratified shale beds.

Cabba soils are used mostly for range, but some areas are dryfarmed.

Typical profile of Cabba silt loam, NW1/4 of section 11, T. 7 S., R. 46 E., in native grass

A1--0 to 7 inches, grayish-brown (10YR 5/2) silt loam, dark grayish brown (10YR 4/2) when moist, weak, fine, granular structure; soft when dry, friable when moist, nonsticky and nonplastic when wet; 2 percent, by volume, is pebbles less than one half inch in diameter; abundant fine roots; calcareous; pH 8.4; clear boundary.

C1--7 to 12 inches, light-gray (10YR 7/2) heavy silt loam, grayish brown (10YR 5/2) when moist; massive; soft when dry, friable when moist, slightly sticky and nonplastic when wet; common lime accumulations in seams and splotches; strongly calcareous; pH 8.0; common fine roots; gradual boundary.

C2--12 to 16 inches, light-gray (10YR 7/1) loam, gray (10YR 5/1) when moist; massive; soft when dry, friable when moist, nonsticky and nonplastic when wet, strongly calcareous; pH 8.0; abrupt boundary.

IIC3--16 inches +, softly consolidated siltstone, sandstone, and shale beds. Roots penetrate the bedrock in fractures and between layers.

The A horizon ranges from silt loam to loam and is 4 to 8 inches thick. It ranges from 10YR to 2.5Y in hue and is 5 or 6 in value. Depth to bedrock ranges from 12 to 18 inches.

Cabba association, 15 to 50 percent slopes (Ca).--This association occurs on uplands and consists of Cabba silt loam, Cabba clay loam, and Midway clay loam. The Cabba soils occupy the upper part of slopes, and the Midway soils occupy the middle and lower parts. A typical area is about 40 percent Cabba silt loam, 15 percent Midway clay loam, and the rest minor soils. The Cabba and Midway soils have profiles similar to those described as typical for their series.

Included with these soils in mapping are areas of Farland silt loam and Barvon soils less than 5 acres in size. These included soils generally are on smooth foot slopes, terraces, and fans. Also included are small areas of Shale outcrop and prominent sandstone ledges on the steep southern slopes. The north-facing slopes normally are smooth and steep.

The soils of this association are well drained, are moderately permeable, and have a medium rate of water intake. Runoff is medium to rapid, and the available water capacity is 2 to 3 inches. The effective rooting depth for crops is about 2 feet and includes rooting into the shattered platy siltstone, sandstone, and clay shale beds. Grass and tree roots extend to a depth of more than 5 feet. These soils have low fertility and organic-matter content. The erosion hazard is moderate where soils are protected by grass and trees, but it is severe in unprotected areas.

These soils are used mainly for grazing. A small amount of marketable timber is produced on the minor Barvon and Farland soils. Less timber is harvested on Cabba silt loam and none on Midway clay loam. Trees grow mainly on north-facing slopes, and in most places stands are poorly stocked and have many grassy openings.

The average site index for ponderosa pine is 51 on Cabba silt loam. The annual yield from unmanaged stands is less than 1,000 board feet per acre. Because ponderosa pine trees root deeply in these soils, there is no windthrow hazard. Erosion is a hazard where overgrazing has removed the grass cover in parklike areas and under thin stands of trees. Seedling mortality is severe; more than 75 percent of the plants die. Competition from plants that interfere with the growth of trees is moderate to severe. (Capability unit VIIe-1; range-soil group 7)

Cushman Series

The Cushman series consists of well-drained soils on uplands. These soils are 20 to 40 inches deep over soft shale. The native vegetation is mid and short grasses. Slopes are 4 to 15 percent, and elevation ranges from 3,200 to 3,500 feet. The annual precipitation is 10 to 15 inches, the average annual soil temperature is 47 to 49° F., and the frost-free season is 115 to 120 days. These soils are associated with Fort Collins, Thurlow, and Elso soils.

Typically the surface layer is light grayish-brown silt loam about 4 inches thick, and the subsoil is grayish-brown clay loam about 11 inches thick. The substratum is light brownish-gray heavy loam and very fine sandy loam. It is underlain by soft shale at a depth of about 26 inches.

The Cushman soils are used primarily for dryfarming and for range.

Typical profile of grass-covered Cushman silt loam that has 4 to 8 percent slopes, 600 feet west, 200 feet north of SW. corner of section 19, T. 1 S., R. 51 E.:

A1--0 to 4 inches, light grayish-brown (10YR 6/2) loam, very dark grayish brown (10YR 3/2) when moist; weak, fine, granular structure; soft when dry, friable when moist, nonsticky and nonplastic when wet; noncalcareous; pH 7.0; gradual boundary.

B2--4 to 12 inches, grayish-brown (10YR 5/2) clay loam, dark grayish brown (10YR 4/2) when moist; moderate, medium, prismatic structure that separates to moderate, medium and fine, blocky; slightly hard when dry, friable when moist, sticky and plastic when wet, thin patchy clay films on ped faces; noncalcareous; pH 7.2; gradual boundary.

B3ca--12 to 15 inches, light olive-brown (2.5Y 5/4) clay loam, olive brown (2.5Y 4/4) when moist; moderate, medium, prismatic structure that separates to moderate, coarse, blocky; slightly hard when dry, friable when moist, sticky and plastic when wet; noncalcareous; pH 7.2; thin patchy clay films on ped faces; gradual boundary.

C1ca--15 to 23 inches, light brownish-gray (2.5Y 6/2) heavy loam, grayish brown (2.5Y 5/2) when moist; mottled with white (2.5Y 8/0) when dry, light gray (2.5Y 7/2) when moist; massive, slightly hard when dry, friable when moist, sticky and plastic when wet; very strongly calcareous; common threads and few small nodules of lime; pH 8.6; abrupt boundary.

C2--23 to 26 inches, light brownish-gray (2.5Y 6/2) very fine sandy loam, grayish brown (2.5Y 5/2) when moist; many, fine, prominent, yellow mottles; massive; soft when dry, friable when moist, nonsticky and nonplastic when wet; very strongly calcareous; lime pockets and flour lime; pH 8.6; gradual boundary.

C3--26 inches, light brownish-gray (2.5Y 6/2) soft sandstone, grayish brown (2.5Y 5/2) when moist; many, fine, prominent, yellow mottles; strongly calcareous; pH 7.6.

The A horizon ranges from 10YR to 2.5Y in hue, is 5 or 6 in value when dry and 3 or 4 when moist, and is 2 or 3 in chroma. It ranges from loam to silt loam or very fine sandy loam. The B horizon, where present, has values of 4 or 5 when dry. The B horizon ranges from clay loam to heavy silt loam. The C1ca horizon has values of 5 or 6 when dry. The depth to soft sandstone or sandy, silty, or clayey shale ranges frmo 20 to 40 inches.

Cushman-Elso silt loams, 4 to 8 percent slopes (Ce).--This complex of soils on uplands consists of moderately deep Cushman silt loam and shallow Elso silt loam. The profiles of these soils are similar to those described as typical for their series. Cushman silt loam occupies long, smooth foot slopes and swales, and Elso silt loam occupies knobs and ridges. A typical area is about 70 percent Cushman soils and 30 percent Elso soils. Included with these soils in mapping are areas of Fort Collins, Thurlow, and McRae soils less than 5 acres in size.

These soils are well drained and have slow runoff and moderate permeability. The available water capacity is 4 to 6 inches in Cushman soils and 2 to 3 inches in Elso soils. These soils blow easily when dry. Organic-matter content and fertility are medium in the Cushman soils and low in the Elso soils. Plant roots penetrate readily to the shale or sandstone.

These soils are used for dryfarmed crops and for range. (Both soils in capability unit IIIe-1, dryland, and range-soil group 4; Cushman soil in windbreak suitability group 2; Elso soil not assigned windbreak suitability group)

Cushman-Elso silt loams, 8 to 15 percent slopes (Ch).--This soil complex occurs on uplands and is about 70 percent Cushman silt loam, 20 percent Elso silt loam, and the rest minor soils. Cushman soils are on smooth foot slopes and in swales, and Elso soils are on knobs and narrow ridges. Included with these soils in mapping are areas of Thurlow, Fort Collins, and McRae soils less than 5 acres in size.

These soils are used mostly for range. A small acreage is used for dryfarmed hay and grain. (Both soils in capability unit IVe-1, dryland, and range-soil group 4; and Cushman soil is in windbreak suitability group 2; Elso soil not assigned windbreak suitability group)

Elso Series

The Elso series consists of well-drained, medium-textured, shallow soils on uplands. These soils formed from softly consolidated shale on foot slopes, narrow ridges, knobs, and tabular divides. The native vegetation is short grasses. Slopes are 8 to 45 percent, and elevation ranges from 3,000 to 3,500 feet. The annual precipitation is about 12 inches, the average annual soil temperature is 47 to 49° F., and the frost-free season is about 115 to 120 days.

Typically the surface layer is light brownish-gray silt loam about 7 inches thick. The subsoil is light brownish-gray silt loam. It is underlain by softly consolidated, interbedded silty, clayey, and sandy shale that lies at a depth of less than 20 inches.

The Elso soils are used mostly for range.

Typical profile of grass-covered Elso silt loam, 8 to 15 percent slopes, 600 feet west and 2,640 feet south of the NE. corner of sec. 3, T. 4 S., R. 51 E.:

A11--0 to 2 inches, light-gray (2.5Y 7/2) silt loam, light olive brown (2.5Y 5/4) when moist; weak, fine, granular structure; soft when dry, friable when moist, nonsticky and nonplastic when wet, strongly calcareous; pH 8.4; gradual boundary.

A12--2 to 7 inches, light brownish-gray (2.5Y 6/2) silt loam, olive brown (2.5Y 4/4) when moist; weak, fine, granular structure, soft when dry, friable when moist, nonsticky and nonplastic when wet, strongly calcareous; pH 8.4; gradual boundary.

C1--7 to 15 inches, light brownish-gray (2.5Y 6/2) silt loam, light olive brown (2.5Y 5/4) when moist; mottled with few lime splotches that are light brownish gray (2.5Y 6/2) and white (2.5Y 8/2) when dry and light brownish gray (2.5Y 6/2) when moist; massive; soft when dry, friable when moist, nonsticky and nonplastic when wet; strongly calcareous; pH 8.4; abrupt boundary.

C2--15 to 20 inches, light-gray (2.5Y 7/2) silt loam, light olive brown and light brownish gray (2.5Y 5/4 and 2.5Y 6/2) when moist; common mottles of yellow and gray; massive; friable when moist, nonsticky and nonplastic when wet, mildly calcareous; pH 8.2.

C3--20 inches, light-gray softly consolidated shale.

The A1 horizon ranges from 3 to 8 inches. It is predominantly silt loam, but includes loam, light silty clay loam, light clay loam, and heavy fine sandy loam. The A1 horizon ranges from 2.5Y to 10YR in hue, and from 5 to 7 in value when dry and more than 3 when moist. The upper 2 to 4 inches of the A1 horizon is noncalcareous in places. Gravelly, cobbly, and stony types may occur where associated with sandstone outcrops. The depth to soft, interbedded shale is shallower than 20 inches or less. The C horizon is silt loam or loam 2 to 14 inches thick. It is strongly calcareous in the upper part and has few segregations of lime in threads or soft nodules.

Elso silt loam, 8 to 15 percent slopes (Ec) This soil occurs on smooth foot slopes, ridges, and narrow tabular divides in the uplands. It is underlain by softly consolidated shale at a depth of less than 20 inches. This soil has the profile described as typical for the series. Included with this soil in mapping are areas of Thurlow, Fort Collins, and Remmit soils less than 5 acres in size.

This soil has medium runoff and moderate permeability. The available water capacity is 2 to 3 inches. The organic-matter content and fertility are low. Bare soil blows easily. Plant roots penetrate the soil readily, and can penetrate the shale layer through fractures.

This soil is used mostly for range. Small areas are used for dryfarmed small grains. (Capability unit VIe-2; range-soil group 4)

Haverson Series

The Haverson series consists of well-drained, medium-textured soils that are more than 60 inches deep. These soils formed in loamy alluvium under short and mid grasses. Slopes are 0 to 4 percent, and elevation ranges from 2,700 to 3,500 feet. The annual precipitation is about 12 inches, the average annual soil temperature is 47 to 49° F., and the frost-free season is about 115 days. These soils are associated with Glenberg, Heldt, and McRae soils.

Typically the surface layer is light brownish-gray silt loam about 6 inches thick. The subsoil and substratum are calcareous grayish-brown and light brownish-gray stratified silt loam, fine sandy loam, and silty clay loam.

The Haverson soils are used mainly for irrigated and dryfarmed hay and small grains.

Typical profile of cultivated Haverson silt loam that has 0 to 2 percent slopes, 1,000 feet south and 600 feet east of the SW. corner of sec. 36, T. 4 S., R. 51 E.:

Ap--0 to 6 inches, light brownish-gray (2.5Y 6/2) silt loam, dark grayish brown (2.5Y 4/2) when moist; weak platy to granular structure; soft when dry, friable when moist, nonsticky and nonplastic when wet; weakly calcareous; pH 8.2; clear boundary.

C1--6 to 20 inches, grayish-brown (2.5Y 5/2) fine sandy loam with 1/2 to 2-inch layer of silt loam, dark grayish brown (2.5Y 4/2) when moist; silt loam material has weak, thin, platy structure, fine sandy loam is massive; soft when dry, friable when moist, nonsticky and nonplastic when wet; weakly calcareous; pH 8.6; clear boundary.

C2--20 to 26 inches, light brownish-gray (2.5Y 6/2) very fine sandy loam and 1/2-inch layers of light brownish gray (10YR 6/2) silt loam, 2 to 3 inches apart, including a 1/2- to 3/4-inch layer of light-gray (2.5Y 7/2) fine sand; massive; soft when dry, friable when moist, nonsticky and nonplastic when wet; weakly calcareous; pH 8.6; clear boundary.

C3--26 to 38 inches, light brownish-gray (10YR 6/2) silt and silt loam in 1/2-inch layers, grayish brown (10YR 5/2) when moist; massive; common, medium and fine pores, few distinct lime specks; slightly hard when dry, very friable when moist, nonsticky and nonplastic when wet; mildly calcareous; pH 8.4; clear boundary.

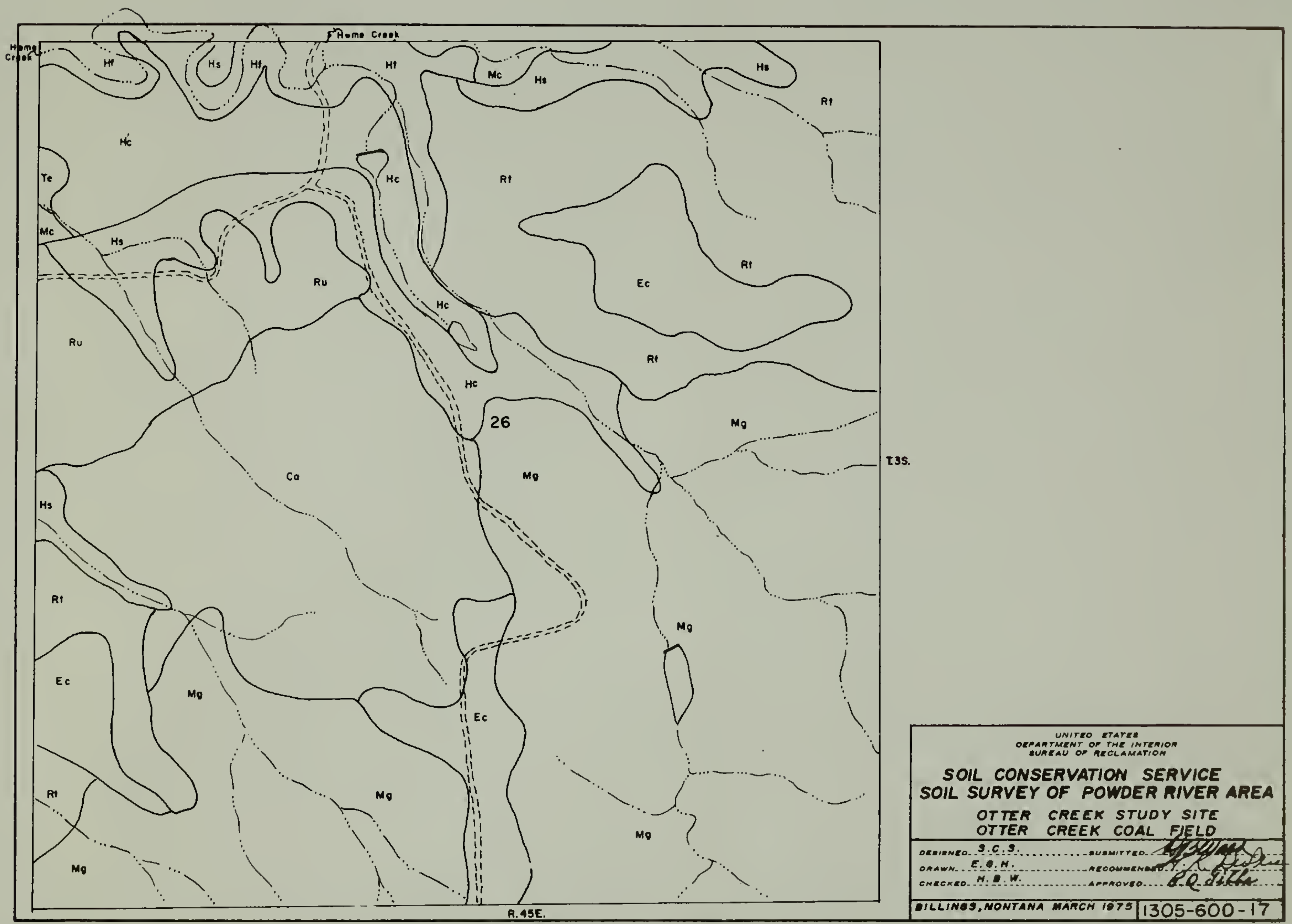
C4--38 to 60 inches, light brownish-gray silt loam, silty clay loam, and very fine sandy loam layers 1/2 inch to 2 inches thick and thin strata of light-gray fine and coarse sand 1 inch thick; massive and thin platy structure; soft when dry, very friable when moist, nonsticky and nonplastic when wet; weakly calcareous; pH 8.2.

The A horizon, 3 to 6 inches thick, ranges from fine sandy loam to silty clay. It ranges from 10YR to 2.5Y in hue, and is 1 or 2 in chroma. The stratified silty and sandy materials of the substratum occur mainly at a depth of 18 to 48 inches.

Haverson silt loam (0 to 2 percent slopes) (Hc).--This soil occurs on flood plains and stream terraces. It is underlain by stratified alluvium at a depth of 20 inches or more. It has the profile described as typical for the series. Included with this soil in mapping are areas of Glenberg fine sandy loam and Haverson silty clay loam less than 5 acres in size.

This soil has slow runoff and moderate permeability. The available water capacity is 9 to 11 inches for a 5-foot depth. The organic-matter content is low, and the fertility is medium. Plant roots penetrate deeply. Fallowed soil blows easily.

This soil is used for dryfarmed or irrigated small grains and alfalfa for hay or seed. Alfalfa hay, wheat, barley, and oats grow well on irrigated soil. (Capability unit IIIc-1, dryland; range-soil group 4; windbreak suitability group 2)



UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

SOIL CONSERVATION SERVICE
SOIL SURVEY OF POWDER RIVER AREA

OTTER CREEK STUDY SITE
OTTER CREEK COAL FIELD

DESIGNED S.C.S. SUBMITTED
DRAWN E.G.H. RECOMMENDED
CHECKED H.B.W. APPROVED

BILLINGS, MONTANA MARCH 1975 1305-600-17

PLATE 28

Haverson soils, channeled (0 to 4 percent slopes) (Hf).--These soils occupy narrow flood plains and coalescing alluvial fans in valleys 100 to 800 feet wide. A typical area is about 85 percent Haverson soils and 15 percent Glenberg, Heldt, and Banland soils in areas less than 2 acres in size. A meandering stream channel 5 to 15 feet wide and 4 to 6 feet deep cuts the valley bottom or flood plain into irregular areas less than 200 feet wide and 1,000 feet long. The streams flow only during spring thaws or after occasional cloudbursts. The drainageways are not tillable, but they make up 10 to 20 percent of the mapping unit. The Haverson soils are moderately permeable and have an available water capacity of about 10 inches.

These soils are used mainly for range. Small fields are used for alfalfa, wheat, barley, and grass. (Capability unit VIw-1; range-soil group 4; windbreak suitability group 2)

Heldt Series

The Heldt series consists of well-drained, deep, calcareous soils on stream terraces, fans, and foot slopes of the uplands. These soils are moderately fine textured. Slopes are 0 to 8 percent, and elevation ranges from 2,500 to 3,500 feet. The annual precipitation is about 12 inches, the average annual soil temperature is 47 to 49° F., and the frost-free season is 115 to 120 days. These soils are associated with the Haverson, McRae, and Glenberg soils.

Typically the surface layer is light brownish-gray silty clay loam about 9 inches thick. The subsoil is grayish-brown silty clay loam. The substratum is light-gray, light brownish-gray, and light yellowish-brown silty clay loam. The lower part of the substratum contains crystals of salt or gypsum.

The Heldt soils are used mostly for dryfarmed alfalfa, grass, and small grains.

Typical profile of Heldt silty clay loam, 0 to 2 percent slopes, 1,050 feet west and 40 feet north of the SE. corner of sec. 33, T. 3 S., R. 50 E.:

Ap1--0 to 5 inches, light brownish-gray (2.5Y 6/2) silty clay loam, dark grayish brown (2.5Y 4/2) when moist; weak, fine and medium, blocky structure; hard when dry, firm when moist, sticky and plastic when wet; mildly calcareous; pH 8.0; diffuse boundary.

Ap2--5 to 9 inches, light brownish-gray (2.5Y 6/2) silty clay loam, grayish brown (2.5Y 5/2) when moist; weak, fine and medium, blocky structure that separates to fine granular; hard when dry, firm when moist, sticky and plastic when wet; mildly calcareous; pH 8.0; diffuse boundary.

B2--9 to 10 inches, grayish-brown (2.5Y 5/2) silty clay loam, dark grayish brown (2.5Y 4/2) when moist; weak prismatic structure that separates to moderate, medium and fine, blocky; hard when dry, firm when moist, sticky and plastic when wet; mildly calcareous; pH 8.2; clear boundary.

C1--10 to 34 inches, light-gray (2.5Y 7/2) silty clay loam, light olive brown (2.5Y 5/4) when moist; weak prismatic structure that separates to moderate, medium and fine, blocky; hard when dry, firm when moist, sticky and plastic when wet; strongly calcareous; pH 8.4; clear boundary.

C2ca--34 to 44 inches, light brownish-gray (2.5Y 6/2) silty clay loam, light olive brown (2.5Y 5/4) when moist; weak, coarse, blocky structure; slightly hard when dry, friable when moist, sticky and plastic when wet; strongly calcareous; common lime specks, threads, and seams along root channels and lime throughout the soil mass; pH 8.4; clear boundary.

C3ca--44 to 62 inches, light yellowish-brown (2.5Y 6/4) silty clay loam, light olive brown (2.5Y 5/4) when moist; massive; slightly hard when dry, friable when moist, sticky and plastic when wet; strongly calcareous; gypsum crystals in seams and small pockets; pH 8.6.

The A horizon ranges from 10YR to 2.5Y in hue, is 5 or 6 in value when dry and 4 or 5 when moist. The A horizon may or may not be calcareous. The Cca horizon has segregated lime in seams and splotches below a depth of 30 inches. In some places thin strata occur below a depth of 30 inches. Gypsum crystals are in seams and pockets below a depth of 42 inches.

Heldt silty clay loam, 4 to 8 percent slopes (He).--This soil is on fans and foot slopes. It is underlain by shale beds at a depth of more than 5 feet. This soil is more sloping than Heldt silty clay loam, 0 to 2 percent slopes, and contains more lime because it receives runoff from calcareous soils at higher elevations.

This soil is mostly in range. Small areas are used for dryfarmed grains and hay. (Capability unit IIIe-1, dryland; range-soil group 5; windbreak suitability group 2)

McRae Series

The McRae series consists of well-drained silt loam soils that are more than 5 feet deep. These soils formed in deep alluvial materials on fan terraces, stream terraces, and foot slopes. The native vegetation is mid and short grasses. Slopes are 0 to 8 percent, and elevation ranges from 3,000 to 3,500 feet. The annual precipitation is about 12 inches, the average annual soil temperature is 47 to 49° F., and the frost-free season is 100 to 120 days. These soils are associated with Heldt, Fort Collins, and Cushman soils.

Typically the surface layer is grayish-brown silt loam about 9 inches thick. The subsoil and substratum are pale-brown calcareous silt loam that extends to a depth of more than 60 inches.

The McRae soils are used for small grains and alfalfa grown for hay or seed. A large acreage is range.

Typical profile of McRae silt loam, 0 to 2 percent slopes; 200 feet north of SE. corner of sec. 10 T. 2 S., R. 50 E.:

A11--0 to 3 inches, grayish-brown (10YR 5/2) silt loam, dark grayish brown (10YR 4/2) when moist; weak, fine, crumb structure; soft when dry, friable when moist, nonsticky and nonplastic when wet; noncalcareous; pH 7.0; gradual boundary.

A12--3 to 6 inches, grayish-brown (10YR 5/2) silt loam, very dark grayish brown (10YR 3/2) when moist; weak platy structure that separates to weak, medium and fine, blocky; slightly hard when dry, friable when moist, nonsticky and nonplastic when wet; noncalcareous; pH 7.0; gradual boundary.

B2--6 to 9 inches, grayish-brown (10YR 5/2) silt loam, brown (10YR 4/3) when moist; weak prismatic structure that separates to moderate, coarse, medium and fine, blocky; slightly hard when dry, friable when moist, nonsticky and nonplastic when wet; noncalcareous; pH 7.6; clear, wavy boundary.

C1ca--9 to 34 inches, pale-brown (10YR 6/3) silt loam, brown (10YR 5/3) when moist; massive; slightly hard when dry, friable when moist, nonsticky and nonplastic when wet; very strongly calcareous; white lime in pockets, splotches, and seams; pH 8.6; clear, wavy boundary.

C2--34 to 48 inches, pale-brown (10YR 6/3) heavy silt loam, brown (10YR 5/3) when moist; massive; soft when dry, friable when moist, slightly sticky and plastic when wet; very strongly calcareous; pH 8.6; gradual boundary.

C3--48 to 65 inches, pale-brown (10YR 6/3) light silty clay loam, brown (10YR 5/3) when moist; massive; soft when dry, friable when moist, sticky and plastic when wet; very strongly calcareous; pH 8.6.

The A1 horizon ranges from 3 to 8 inches in thickness. It ranges from 10YR to 2.5Y in hue and is 5 or 6 in value when dry and 3 or 4 when moist. The B2 horizon ranges from silt loam to heavy silt loam. It ranges from 10YR to 2.5Y in hue, is 4 or 5 in value when dry, and is 2 or 3 in chroma. The Cca horizon has segregated lime in splotches and threads. The solum ranges from 9 to 12 inches in thickness and the Cca horizon ranges from 20 to 26 inches. The Cca horizon rests on loamy stratified material in places.

McRae silt loam, 0 to 2 percent slopes (Mc).--This soil is on fan terraces and stream terraces. It formed in silt loam alluvium that is more than 5 feet deep and has the profile described as typical for the series. Included with this soil in mapping are areas of Heldt and Fort Collins soils less than 5 acres in size.

Runoff is slow and permeability is moderate. The available water capacity is 10 to 12 inches for a 5-foot depth. Organic-matter content is medium and fertility is high. The hazard of erosion is slight.

This soil is used mainly for range and irrigated small grains. Some alfalfa is grown for hay and seed. Alfalfa hay, wheat, barley, and oats grow well on irrigated soil. (Capability unit IIIc-1, dryland; range-soil group 4; windbreak suitability group 2)

McRae silt loam, 2 to 4 percent slopes (Md).--Except for stronger slopes, this soil is similar to McRae silt loam, 0 to 2 percent slopes. Runoff is slow to medium, and the hazard of soil blowing is moderate. Included with this soil in mapping are areas of Hesper, Fort Collins, and Heldt soils less than 5 acres in size.

This soil is used mainly for range and for small grains. Some alfalfa is grown for hay and seed. (Capability unit IIIa-1, dryland; range-soil group 4; windbreak suitability group 2)

McRae silt loam, 4 to 8 percent slopes (Me).--Except for stronger slopes and thicker deposits of alluvium, this soil is similar to McRae silt loam, 0 to 2 percent slopes. Runoff is medium and the erosion hazard is moderate. This soil occurs on fans and foot slopes. Included with this soil in mapping are areas of Hesper, Fort Collins, and Heldt soils less than 5 acres in size.

This soil is used mostly for range. Some areas are used for dryfarmed small grains and hay. (Capability unit IIIe-1, dryland; range-soil group 4; windbreak suitability group 2)

Midway Series

The Midway series consists of well-drained, moderately fine textured soils that are underlain by shale, generally at a depth of less than 20 inches. These soils are on uplands under a cover of short grasses. Slopes are 2 to 75 percent, and elevation ranges from 3,000 to 4,000 feet. The average annual precipitation is about 12 inches, and the average annual soil temperature is 47 to 49° F., and the frost-free season is 100 to 120 days. These soils are associated with Elso, Kyle, Thurlow, and Ocean Lake soils.

Typically the surface layer is light yellowish-brown clay loam and clay 7 inches thick. The substratum is light brownish-gray interbedded silty, clayey, and sandy material underlain by softly consolidated pale-olive clayey shale at a depth of 7 to 20 inches. Salt and gypsum crystals are interbedded between the shale layers below a depth of 10 inches.

Midway soils are used primarily for range.

Typical profile of silty clay loam, 2 to 8 percent slopes, 300 feet east of N1/4 corner of sec. 23, T. 3 S., R. 49 E.:

A1--0 to 3 inches, light yellowish-brown (2.5Y 6/4) clay loam, light olive brown (2.5Y 5/4) when moist; weak, thin, platy structure that separates to fine granular structure; soft when dry, friable when moist, sticky and plastic when wet; strongly calcareous; pH 8.4; gradual boundary.

AC--3 to 7 inches, light yellowish-brown (2.5Y 6/4) light clay, light olive brown (2.5Y 5/4) when moist; massive; thin platy silty clay loam and clay loam shale fragments; sticky and plastic when wet; strongly calcareous; pH 8.0; abrupt boundary.

C1--7 to 14 inches, light brownish-gray (2.5Y 6/2) interbedded silty, clayey, and sandy shale, light olive brown (2.5Y 5/6 and 5Y 5/3) when moist; mottled with light gray (2.5Y 7/2); masses of gypsum crystals between thin shale plates; strongly calcareous; pH 8.0; abrupt boundary.

C2--14 inches, pale-olive (5Y 6/3) interbedded silty and clayey shale that has gypsum crystals between shale plates at varying depths; shale is mottled with black, yellowish, and brownish colors; strongly calcareous.

The A horizon ranges from clay loam or silty clay loam to light clay or light silty clay. It ranges from 10YR to 2.5Y in hue, is 5 or 6 in value when dry, and 4 or 5 when moist, and ranges from 2 to 4 in chroma. The depth to shale ranges from 7 to 20 inches. The shale is silty, sandy, and clayey. In places segregated lime occurs in the AC horizon, and abundant gypsum crystals are between the shale plates at a depth of 10 to 14 inches.

Midway silty clay loam, 2 to 8 percent slopes (Mf).--This soil occurs on divides and ridges of the uplands. It has the profile described as typical for the series. Included with this soil in mapping are areas of Elso, Ocean Lake, and Thurlow soils less than 5 acres in size.

This soil is slowly permeable, and at depths of more than 2 feet, roots penetrate only through fractures in the shale. This soil is low in organic-matter content and fertility. The available water capacity is 1 to 3 inches, and runoff is slow to medium. The erosion hazard is slight to moderate.

This soil is used for range. (Capability unit VIe-2; range-soil group 5)

Midway-Elso association, 8 to 35 percent slopes (Mg).--This association is made up of Midway clay loam and Elso silt loam. In most places, the Midway soil occupies the lower foot slopes and valley sides and the Elso soil occupies the narrow divides, ridgetops, knolls, and upper part of the valley sides. The valley sides are cut by numerous gullies that join to form larger drainageways. These gullies are 50 to 100 feet apart at their widest spacing, and between them is 1 to 15 acres of soils that are smooth and gently sloping. These soils normally are in the Thurlow, Cushman, and Fort Collins series. Typically this association is about 60 percent Midway soils, 30 percent Elso soils, and 10 percent other soils. Midway and Elso soils have profiles similar to those described as typical for their series. Permeability is slow in Midway soils and moderate in Elso soils. Runoff is medium to rapid, and the erosion hazard is moderate to severe. Where gully erosion is active, broken slopes and shale exposures are common.

The soils in this association are too steep and too shallow for cultivation. They are used for range. (Capability unit VIIe-1; range-soil group is 8 for Midway soil and 7 for Elso soil)

Ringling Series

The Ringling series consists of well-drained loamy soils less than 20 inches deep over porcelanite shale beds. The native vegetation is mid grasses and sparse trees. Slopes are 6 to 50 percent, and elevation ranges from 3,500 to 4,500 feet. The annual precipitation is 15 to 19 inches, the average annual soil temperature is 45 to 47° F., and the frost-free season is 90 to 100 days. These soils are associated with Relan, Fergus, and Cabba soils.

Typically the surface layer is weak-red slaty loam about 16 inches thick. The substratum is shattered porcelanite shale.

The Ringling soils are used mostly for range.

Typical profile of Ringling slaty loam, 20 to 50 percent slopes, 1,600 feet east and 600 feet north of SW. corner of section 11, T. 3 S., R. 50 E.:

A1--0 to 9 inches, weak-red (2.5YR 5/2) slaty loam, dusky red (2.5YR 3/2) when moist; moderate, fine, granular structure; soft when dry, friable when moist, nonsticky and nonplastic when wet; noncalcareous; pH 7.6; 30 percent porcelanite shale fragments 1/4 to 1 inch in size; abrupt boundary.

AC--9 to 16 inches, pale-red (2.5YR 6/2) very slaty loam, weak red (2.5Y 5/2) when moist; 85 percent porcelanite shale fragments 1 inch to 3 inches in size; strongly calcareous; pH 8.4; lime coatings on all sides of shale fragments; gradual boundary.

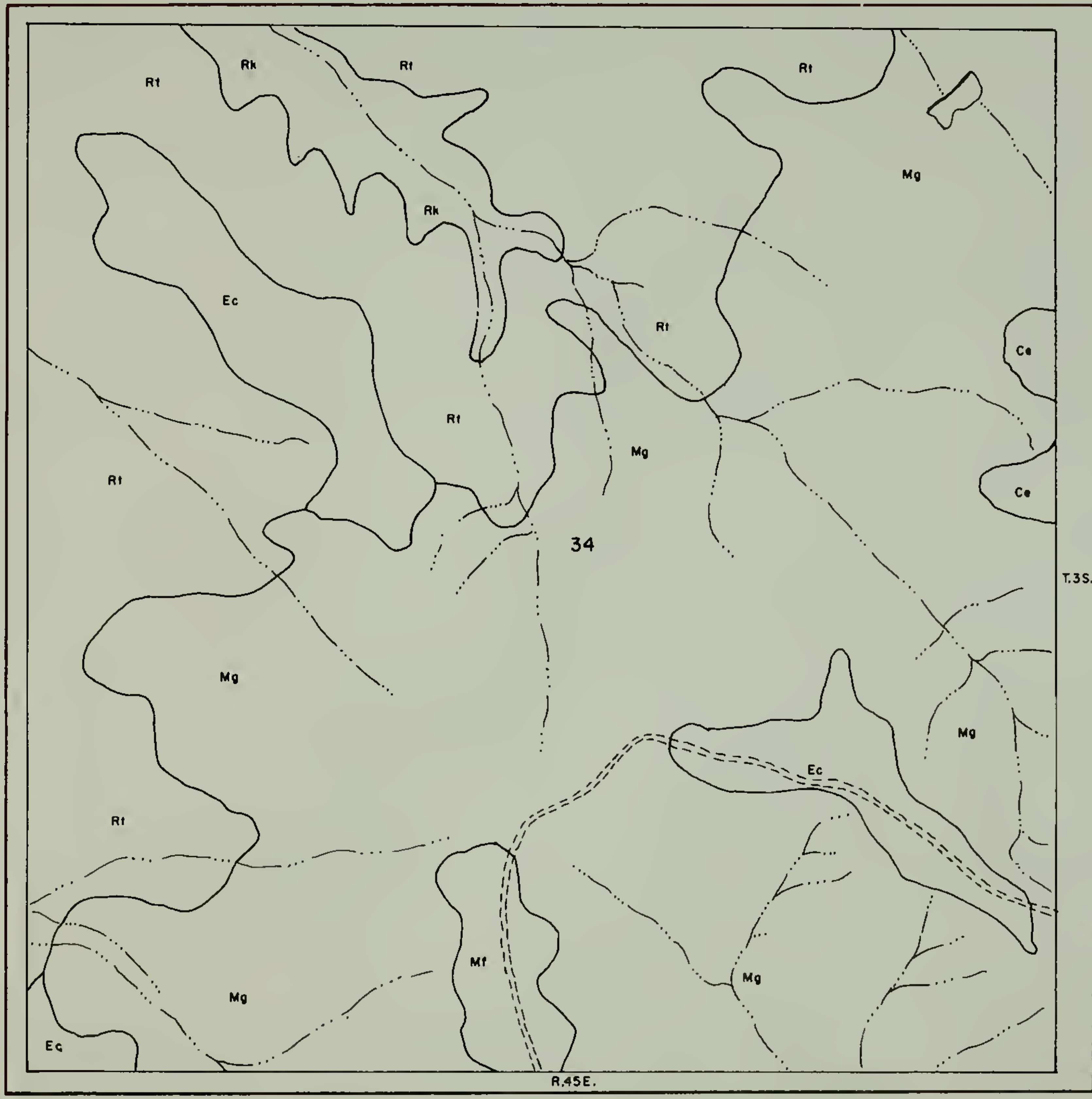
C1--16 to 50 inches, partly weathered reddish-brown porcelanite shale; 95 percent porcelanite fragments more than 6 inches wide; very strongly calcareous; pH 8.0; abrupt boundary.

C2--50 inches, shattered porcelanite shale; no soil

The A1 horizon ranges from 5 to 9 inches in thickness and is slaty silt loam and slaty loam. ranges from 2.5YR to 7.5YR in hue, is 4 or 5 in value when dry and 2 or 3 when moist, and is 2 or 3 in chroma. Depth to bedded porcelanite containing 5 percent or less soil material ranges from 6 to 16 inches. The porcelanite in the A1 horizon ranges from 15 to 75 percent. Lime coats are common on the underside of shale fragments in the upper few inches of the porcelanite beds. Below a depth of 10 inches lime coatings completely cover the shale fragments.

Ringling-Cabba association, 15 to 50 percent slopes (Rt).--This association of soils on uplands consists of about 50 percent Ringling slaty loam and 50 percent Cabba silt loam. Runoff is slow to medium on the Ringling soils and rapid on the steep Cabba soils. Included with these soils in mapping are areas of Relan, Rapalja, Farland, and Kyle soils less than 15 acres in size. These included soils occupy short foot slopes, swales, and U-shaped drainageways. Also included are small areas of Campspass and Barvon soils on north-facing slopes.

The soils of this association are used for range. The only trees harvested commercially grow on the small isolated areas of Campspass or Barvon soils on north-facing slopes.



UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

SOIL CONSERVATION SERVICE
SOIL SURVEY OF POWDER RIVER AREA

OTTER CREEK. STUDY SITE
OTTER CREEK COAL FIELD

DESIGNED	S.C.S.	SUBMITTED	
DRAWN	E.G.H.	RECOMMENDED	
CHECKED	H.B.W.	APPROVED	R.Q. Gibbs

BILLINGS, MONTANA MARCH 1975 | 1305-600-18

Trees grow poorly on Ringling and Cabba soils. The site index for ponderosa pine is 30 on Ringling soils and 15 on Cabba soils. Because ponderosa pine trees root deeply, there is no windthrow hazard. The hazard of erosion is moderate on stock trails and on road grades that have no cross-trenches and are not outshaped. Seedling mortality is severe although plant competition is slight or none. (Capability unit VIIe-2 for both types of soils; range-soil group 13 for Ringling soils and 7 for Cabba soils)

Ringling-Relan association, 6 to 25 percent slopes (Ru).--This association of soils on uplands is made up of about 50 percent Ringling silty loam and 50 percent Relan loam. The Ringitng soils occupy steep knobs, ridges, and narrow divides; the Pelan soils are on lower foot slopes, swales, and drainageways. Runoff is slow to medium on these soils, and the erosion hazard is moderate. Included with these soils in mapping are small areas of Fergus and Farland soils less than 5 acres in size. Also included are areas 5 to 10 acres in size that have clinker outcrops over 30 percent of the ground surface. Clinkers 2 to 5 feet in diameter are common on the landscape and generally occur on convex slopes.

The soils of this association are used for range. Small, isolated areas of Relan soils are used for dryfarmed small grains, grasses, and alfalfa for hay and seed. (Capability unit VIIe-2 for Ringling soils and VIe-1 for Relan soils; range-soil group 13 for Ringling soils and 3 for Relan soils; windbreak suitability group 1 for Relan soils and not assigned for Ringling soils)

Relan Series, Gravelly Variant

The gravelly variant from the Relan series consists of well-drained, medium-textured soils on alluvial fans and terracas. These soils formed in gravelly loam alluvium under mid and short grasses. Slopes are 4 to 8 percent, and elevation ranges from 3,000 to 3,200 feet. The annual precipitation ranges from 15 to 19 inches, the average annual soil temperature is 45 to 47° F., and the frost-free season is about 100 days. These soils are associated with Fergus soils.

Typically the surface layer and upper part of the subsoil are brown gravelly loam that extends to a depth of about 20 inches. The lower part of tha subsoil and the substratum are light-brown, stratifiad gravelly loam and very gravelly sandy loam to a depth of more than 60 inches.

The Relan gravelly variant is used mostly far range.

Typical profile of Relan gravelly loam, gravelly variant, 4 to 8 percent slopes, 300 feat north and 2,640 feet east of tha SW. cornar of sec. 20, T. 3 S., R. 45 E.:

A1--0 to 3 inches, brown (7.5YR 5/2) gravelly loam, dark brown (7.5YR 3/2) when moist; weak, thin, platy structure that separates to waak, fine, granular; soft when dry, friable when moist, nonsticky and nonplastic when wet; mildly calcareous; pH 7.4; abrupt boundary.

B2--3 to 14 inches, brown (7.5YR 5/2) gravelly heavy loam, dark brown (7.5YR 3/2) when moist; moderate, medium and fine, blocky structure, soft when dry, friable when moist, nonsticky and nonplastic when wet; strongly calcareous; pH 7.8; clear boundary.

C1--14 to 20 inches, brown (7.5YP 5/4) gravelly loam, dark brown (7.5YR 3/4) when moist; massive; soft when dry, very friable when moist, nonsticky and nonplastic when wet; 5 percent, by volume, is flat porcelanite chips and 1 percent, by volume, is pebbles 2 1/2 to 3 inches in size; strongly calcareous; lime coatings on pebbles; pH 8.2; clear boundary.

C2--20 to 60 inches, light-brown (7.5YR 6/4) very gravelly sandy loam, dark brown (7.5YR 4/4) when moist, massive; soft when dry, very friable when moist, nonsticky and nonplastic when wet; very strongly calcareous; pH 8.8.

Some areas have many large clinker stones on the surface. The A horizon ranges from 7.5YR to 2.5YR in hue, is 5 or 6 in value when dry, and is 2 to 4 in chroma. The C horizon ranges from 7.5YR to 2.5YR in hue, is 5 or 6 in value, and ranges from 2 to 4 in chroma. The C2 horizon is sandy loam or loam. It is more than 35 percent coarse fragmenrs.

Relan gravelly loam, gravelly variant, 4 to 8 percent slopes (Rk).--This soil occurs on alluvial fans and terraces in the valley of Otter Creek. Slopes are short and dominantly 6 percent. On narrow terraces this soil is underlain by very gravelly loam or coarse sand at a depth of more than 48 inches. Included with this soil in mapping are areas of Relan and Fergus soils less than 5 acres in size.

Runoff is medium and permeability is rapid. Tha available water capacity is about 5 to 6 inches for a 5-foot depth. Organic-matter content and fertility are low. The erosion hazard is slighr.

This soil is used mainly for range. It is fairly well suited to small grains and alfalfa grown for seed or hay. (Capability unit IIIe-3, dryland; range-soil group 3; windbreak suitability group 1)

Hopley Series

The Hopley series consists of well-drained, medium-textured soils that are more than 40 inches deep. These soils occur on fans, foot slopes, and stream terraces. They formed in loamy alluvium under mid and short grasses. Slopes are 4 to 8 percent, and elevation ranges from 3,000 to 4,000 feet. The annual precipitation is 15 to 19 inches, the average annual soil temperature is 45 to 47° F., and the frost-free season is 100 to 115 days. These soils are associated with Pelan, Farland, and Fergus soils.

Typically the surface layer is dark grayish-brown loam about 5 inches thick. The subsoil is brown and grayish-brown loam about 21 inches thick. The substratum is light brownish-gray loam that is strongly calcareous and is underlain by shale at a depth of about 42 inches.

The Hopley soils are used mostly for grazing.

Typical profile of Hopley loam that has 4 to 8 percent slopes, 900 feet west and 2,640 feer south of the NE. corner of sec. 4, T. 3 S., P. 50 E.:

Ap--0 to 5 inches, dark grayish-brown (10YP 4/2) loam, very dark grayish brown (10YR 3/2) when moist; moderate, thin, platy structure that breaks to weak, fine, granular; soft when dry, friable when moist, nonsticky and nonplastic when wet; noncalcareous; pH 7.0; clear boundary.

B2--5 to 11 inches, brown (10YR 5/3) loam, dark brown (10YR 4/3) when moist; moderate, medium, prismatic structure that separates to moderate, medium and fine, blocky; hard when dry, friable when moist, slightly sticky and slightly plastic when wet; noncalcareous; pH 7.4; clear boundary.

B3--11 to 26 inches, graylsh-brown (10YR 5/2) loam, dark grayish brown (10YR 4/2) when moist; moderate, medium and fine, blocky structure; hard when dry, friable when moist, slightly sticky and slightly plastic when wet; mildly calcareous; common distinct threads and seams of segregated lime; pH 7.8; gradual boundary.

C1ca--26 to 42 inches, light brownish-gray (2.5Y 6/2) loam, grayish brown (2.5Y 5/2) when moist; massive; hard when dry, friable when moist, slightly sticky and slightly plastic when wet; strongly calcareous; common distinct lime segregations; pH 8.2; clear boundary.

C2--42 inches, light-gray (2.5Y 7/2) shale; strongly calcareous; pH 8.4.

The A horizon ranges from 4 to 8 inches in thickness. It is 10YR in hue and 4 or 5 in value when dry and 3 moist. The B horizon is 4 or 5 value dry and 2 or 3 moist. The B and C horizons are less than 18 percent noncarbonate clays. The depth to the Cca horizon ranges from 10 to 26 inches. All horizons are about 1 percent porcelanite shale chips, by volume. Baked porcelanite shale occurs at a depth of 40 to 70 inches.

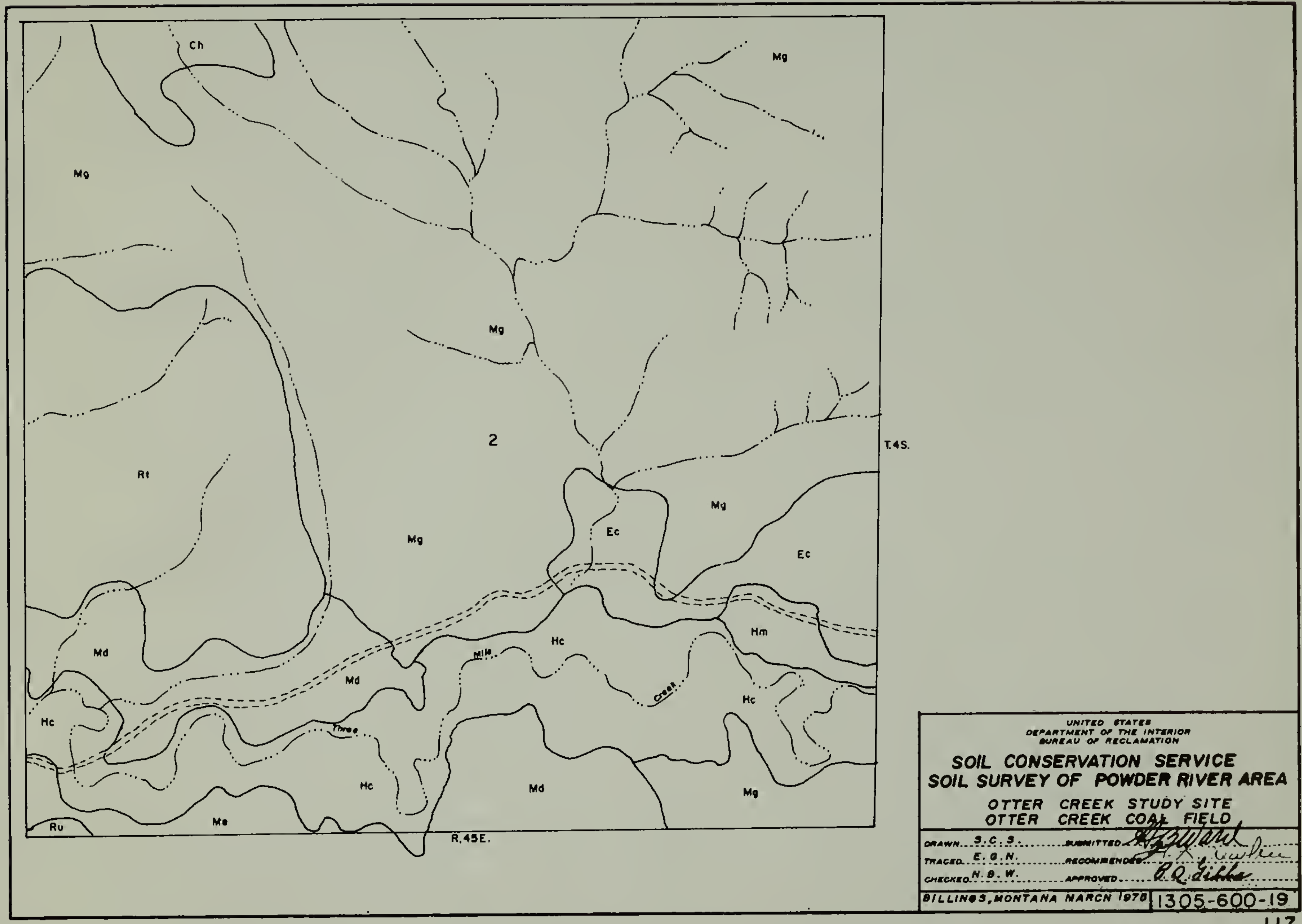
Hopley and Relan loams, 4 to 8 percent slopas (Hs).--This unit consists of undifferentiated areas of Hopley loam and Relan loam on smooth terraces, fans, and short foot slopes. These soils are moderately permeable and have medium runoff. They are moderaraly high in fertility. The available watar capacity is 6 to 8 inches. Included with these soils in mapping are areas of Farland and Fergus soils less than 2 acres in size.

These soils are mostly in ranga. Small areas are used for dryfarmed small grains and alfalfa grown for hay or seed. (Capability unit IIIe-3, dryland; range-soil group 3; windbreak suitabiliry group 1)

Terrace Escarpments

Terrace escarpments (8 to 35 percent slopes) (Te) consists of escarpments, breaks, and ledges in very deep loamy and clayey materials. This land type occupies smooth rounded breaks and walled drainageways 100 to 200 feer wide. In most places the drainageways are eroded by channels 4 to 6 feet deep and 10 to 20 feet wide. Runoff is rapid, and the erosion hazard is severe. Vegetation is very sparse, and many areas are barren.

This land type is used mainly for limited grazing. (Capability unit VIIe-1; range-soil group 7)



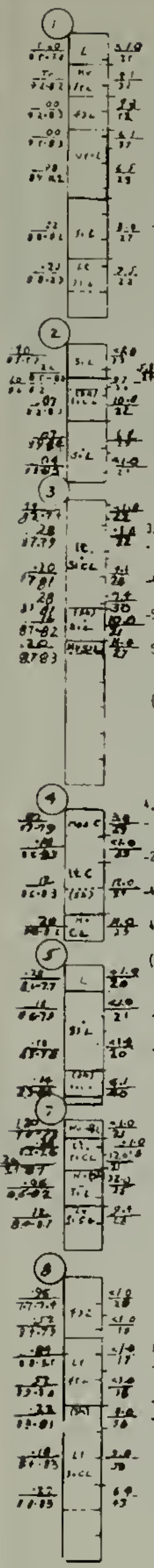
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

SOIL CONSERVATION SERVICE
SOIL SURVEY OF POWDER RIVER AREA

OTTER CREEK STUDY SITE
OTTER CREEK COAL FIELD

DRAWN S.C.S. SUBMITTED
TRACED E.G.N. RECOMMENDED
CHECKED N.B.W. APPROVED

BILLINGS, MONTANA MARCH 1978 | 1305-600-19



1.
-14" good for use on surface
-28" fair for surface best below 24"
-76" unsuited for surface best use below 60" saline alkali
-120" poor for surface best use below 36" saline and alkaline

2.
-12" fair for use on surface
-16" fair for surface best below 6"
-20" poor for surface best below 24"
-64" unsuited for use on surface best use is below 36"
(Total depth 64")

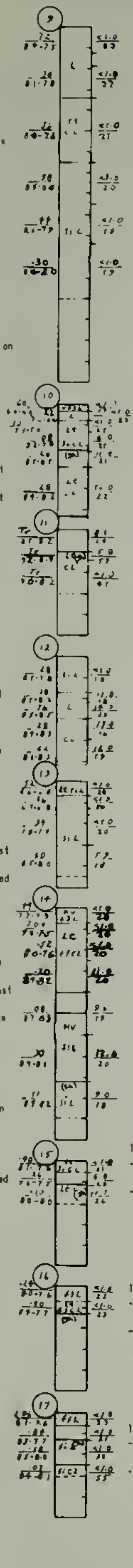
3.
- 8" good for use on the surface
-44" fair for surface best use below 8"
-50" poor for surface best below 12"
50"+ siltstone unsuited for surface best use below 36" saline alkali
(total depth 72")

4.
- 2" good for use on the surface
-24" poor for surface best below 12"
-48" unsuited for surface best below 36"
48"+ shale best use below 36" saline-alkali
(Total depth 60")

5.
- 6" good for use on surface
-48" fair for surface best use below 6"
48"+ silty shale unsuited for surface best use below 24"
(Total depth 64")

7.
- 8" good for use on the surface
-16" good for surface best use below 6"
-22" unsuited for surface best use below 36"
22"+ silty shale saline alkali best use below 36" (total depth 48")

8.
- 6" excellent for use on the surface
-18" good for surface
-60" good for surface best use below 6"
60"+ silty shale unsuited for surface best use below 36"
(total depth 108")



9.
-16" good for surface
-40" good for surface
-156" suitable for surface best use below 6"
(total depth 156")

10.
- 8" fair to good for use on surface
-27" poor for surface best use below 12"
-36" unsuited for surface best below 36"
36"+ silty shale, slt. alkaline best use below 36"
(total depth 64")

11.
- 2" good for use on the surface
- 6" fair for surface best use below 6"
-16" unsuited for use above 36"
16"+ silty shale non saline alkali best use below 36"
(Total depth 36")

12.
-20" good for use on the surface
-62" unsuited for surface best use below 24" very saline slightly alkaline
(Total depth 62")

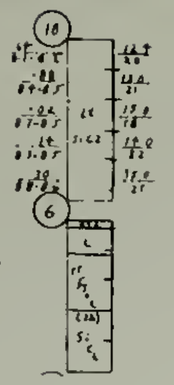
13.
- 8" good for use on the surface
-57" good for surface best use below 6"
57"+ silty shale unsuited for surface best use below 36"
(total depth 57")

14.
-14" good for use on the surface
-30" good for surface
-98" unsuited for use on the surface best use below 36" highly saline slightly alkaline
(total depth 120")

15.
- 5" fair for use on surface
-14" poor for surface best use below 12"
14"+ clayey shale unsuited for surface best use below 36"
(total depth 24")

16.
- 5" good for use on surface
-16" good for surface best use below 6"
16"+ consolidated layered sandstone unsuited for surface best use below 12"
(total depth 21")

17.
- 6" excellent for use on surface
-16" good for surface best use below 16"
16"+ weakly consolidated siltstone best use below 12"
30"+ clayey shale best use below 36"
(total depth 36")



18.
-64" Entire profile is saline alkali and should be placed below 60" in a reconstructed profile should not be mixed with soil used in upper 60"

6.
- 4" fair for use on the surface
-14" poor for surface best use below 6"
-30" poor for surface best use below 12"
-36" unsuited for surface best use below 36"
36"+ shale unsuited for surface best use below 36"
(total depth 64")

Location and Extent of Useable Overburden

Section 26, T. 3 S., R. 45 E.

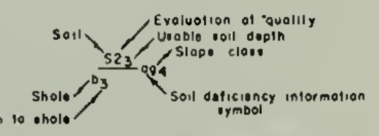
Area	Acres	Horizon A (Inches)	Horizon A/B (Inches)	Horizon B/C (Inches)	Horizon C (Inches)	Total (Inches)
NE¼						
A1	2.0	4.0	12.0	48.0		64.0
A2*	5.6	2.3	2.3			4.6
A3	2.2	8.0	8.0	30.0		46.0
A4**	6.8	4.5	4.5			9.0
A5*	29.1	0.6				0.6
A6*	21.5	1.4		1.1		2.5
A7	8.2	4.6	4.1	35.7	(G)14.0	58.4
A8	4.1	5.1	4.1		25.6	34.8
A9	5.5		21.8		43.6	65.4
A10	5.8	12.5			18.2	30.7
A11	2.8	6.0		20.0	22.7	48.7
A12**	3.7		5.4		24.0	29.4
NW¼						
B1a	1.3	5.1	6.8	33.8	(G)60.0	105.7
B1b	2.4	6.0	8.0	40.0	60.0	114.0
B2b	3.0	5.4	10.8	16.2		32.4
B3*	7.8	4.0		60.0		64.0
B4	3.6	6.0	10.0	70.0		86.0
SW¼						
C1	3.1	11.7		30.2	(G)50.3	92.2
C2*	4.2	1.0		5.0	(G)35.0	41.0
C3	4.9	4.5	7.5		(G)23.6	35.6
C4	3.8	6.9	8.0		(G)70.0	84.9
C5*	1.7	1.6			(G)72.0	73.6
C6	8.4	6.9	6.3		97.0	110.2
C7**	18.1	5.3	8.8	15.9	(G)44.8	74.8
C8**	10.0	3.0			(NaS)10.0	13.0
C9**	6.5	5.8	2.1		G(NaS)14.2	22.1
C10	6.5	4.3		9.3	G(NaS)30.0	43.6
C11	2.5		12.0	60.0		72.0
C12*	12.5	0.6		3.2		3.8
C13	2.3	6.0		10.0	(G)50.0	66.0
C14*	1.6			8.0		8.0
C15	5.3	4.6	17.0		(S)50.0	71.6
C16	2.0	18.0		42.0	(S)48.0	108.0
C17*	10.1	0.8		2.4	(G)16.7	19.9
C18	3.9	4.8		52.0		56.8
SE¼						
D1	7.8*		16.0			16.0
D2	6.4		6.4		(NaS)48.0 (G)30.0	54.4
D3	5.2*	2.1		2.9	G(NaS)48.0	53.0
D4	10.6		24.0		(NaS)36.0	60.0
D5	10.6**	5.5	12.2		(NaS)15.2 G(NaS)13.8	46.7
D6	21.4*	1.7	6.3		(G)56.5	64.5
D7	1.4*				(GNaS)60.0	60.0
D8	6.2	8.0	8.0	40.0	(G)30.0	86.0
D9	6.9*		1.5		(G)47.8	49.3
D10	5.7	8.0	6.0	20.0	(NaS)68.0 (GS)22.0	124.0
D11	4.9**	3.8		(NaS)8.0	18.3	30.1
D12	0.7	14.0			14.0	28.0
D13	5.0*	0.6			30.0	30.6
D14	15.3	4.2		11.2	20.9	36.3
D15	7.7*	0.6			(GNaS)60.0	60.6
D16	1.2	0.5		0.7	(G)36.0	37.2
D17	17.1	4.6	4.0	29.9	(G)19.9	58.4
D18	1.9*			8.0	(G)60.0	68.0
D19	9.7	6.8		(Sp)16.0	(NaS)14.4 G(NaS)25.4	62.6
D20	1.1*	2.7		5.4	60.0	68.1
D21	2.2	10.0	12.2	60.0		82.2
D22	1.3*			6.0	6.0	12.0
D23	3.8*	2.5		2.5		5.0
D24	4.7	10.0	10.0	76.0		96.0

Explanation:

*	Topographic and soil limitations most likely will preclude stripping and stockpiling surface material.
**	Topographic and soil limitations will limit stripping part of the area.
(NaS)	Saline-alkali
(s)	Saline moderate to high
(Na)	Sodic
(G)	Material from geologic strata
(p)	Restricted permeability
(h)	Clay

Horizons Reconstructed Profile: (A) 0 - 6", (B) 0 - 12", (BC) 6 - 24", (C) 24"+

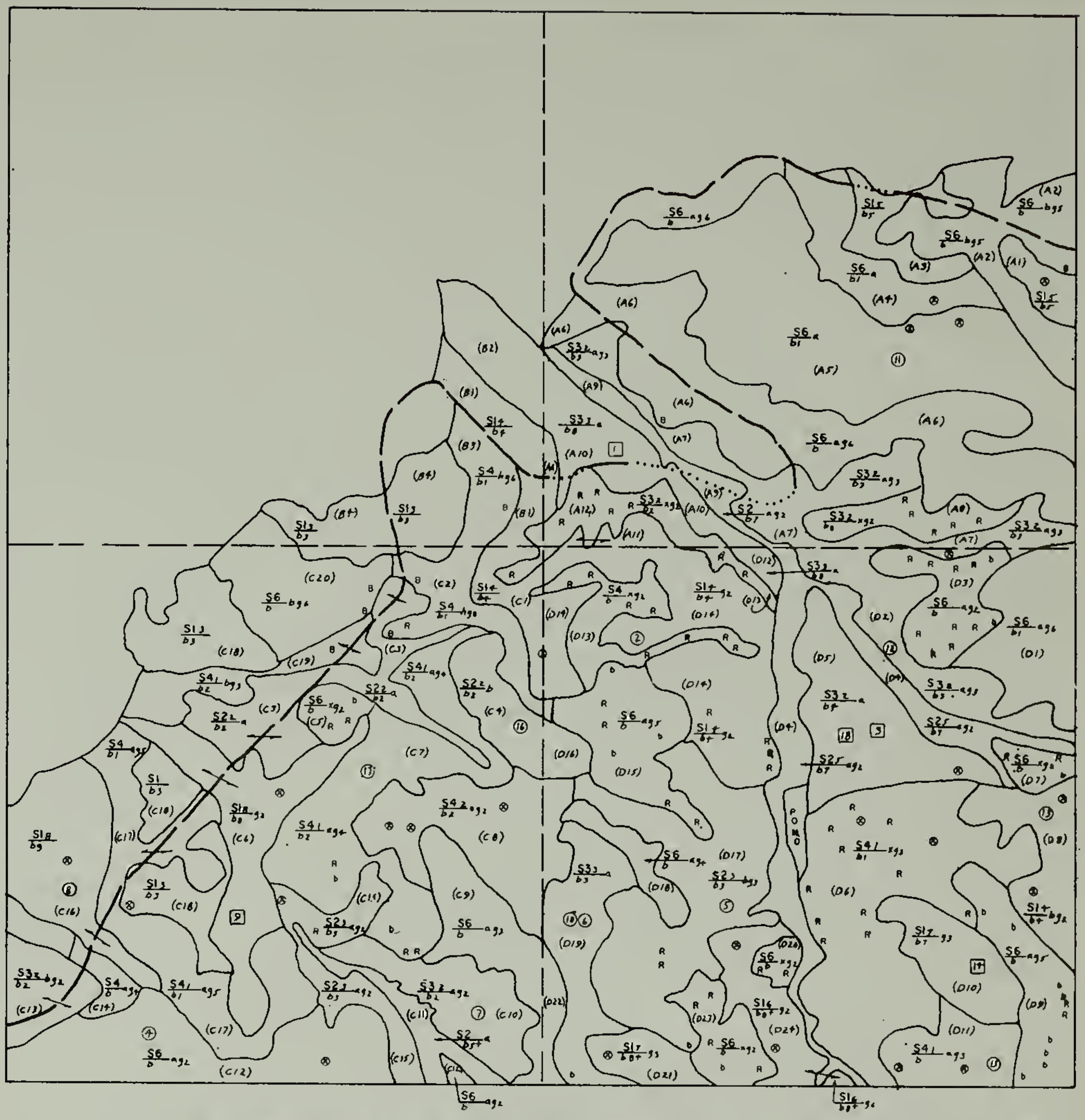
EXPLANATION



INFORMATIVE SYMBOLS

SLOPE		PRINCIPAL SOIL DEFICIENCY			
	0 - 3 Percent	a	Salinity and/or alkalinity	R	Burned rock
g_2	3 - 7 Percent	b	Depth to shale	r	Massive surface rock
g_3	7 - 12 Percent	h	Clay	c	Exposed shale
g_4	12 - 20 Percent	p	Permeability		Alkaline
g_5	20 - 35 Percent	q	Limited moisture retention	#	Greasewood
6	35 - 75 Percent	R	Surface rock (large)		
		X	Surface gravel or stone (small)		
		V	Coarse texture		

General or average depth to shale in feet, absence of subscript indicates a depth range 0 to 1 foot.



	S1 d/10 b/10-18	S1 d/4-6 b/4-8	S1/g2 d/4-10 b/4-10	S1/g3 d/5-10 b/8-10	S2/a-b-h d/3-5 b/5-10	S2/a-b-h d/3(g2)5-10	S2/a-b-h d/3(g3)3-4	S3/a-b-h d/2 b/3	S3/a-b-h-x d b/1-3(g2)1-3	S3/a-h-b d b/2-7(g3)2-7	S3/a-b-K d b/2-3(g4)2-3	S4/a-h-b d/1-2 b/1-2	S4/a-b-h d b/0-1(g3-g4)0-1	S4/a-b-h d/5-6 b/0-1	S5/a-b-h	S6/a-b-h g/2-4 b/0-1	S6/a-b-h g/5-6 b/0-1	Total
Sec. 2-4-45	74.4	3.7	21.0	29.2	16.1	8.4	22.6	4.2		14.7	20.4	3.5	53.7	60.3		13.0	94.4	439.6
Sec. 26-3-45	8.7	48.2	21.6	5.2	26.6	5.4	16.6	36.0	11.7	21.2		14.8	48.1	20.4	29.1	36.2	69.8	419.6
Sec. 34-3-45	5.6	15.4		16.8	47.2	24.8		4.2	19.8	40.8	16.6	4.9	111.7	5.9		56.6	69.1	439.4
Total	88.7	67.3	42.6	51.2	89.9	38.6	39.2	44.4	31.5	76.7	37.0	23.2	213.5	86.6	29.1	105.8	233.3	1298.8

N

SEC 26, T4S, R45E
POWDER RIVER CO.

400 0 400 800 1200
SCALE OF FEET

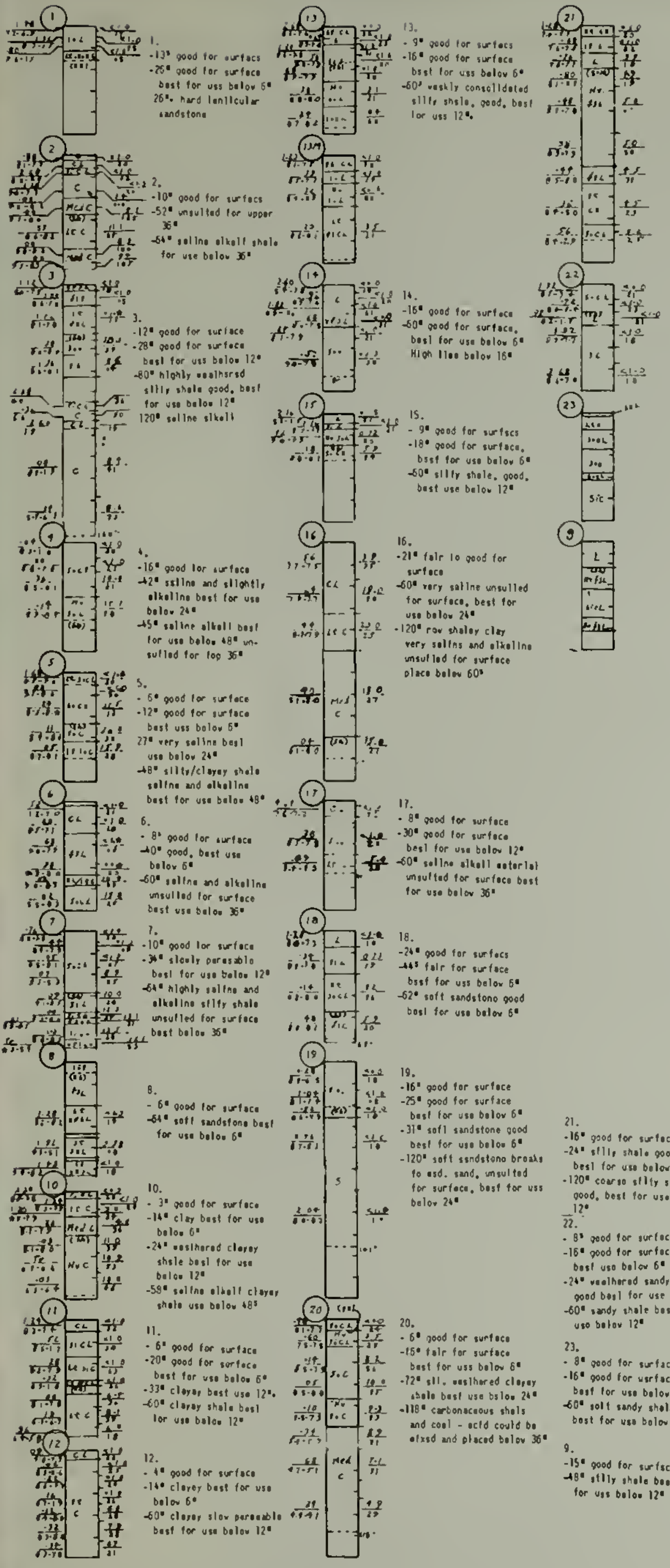
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

DETAILED LAND CLASSIFICATION

OTTER CREEK STUDY SITE
OTTER CREEK COAL FIELD

DESIGNED M.B.WARD — SUBMITTED
DRAWN E.Q.M. — RECOMMENDED
CHECKED M.B.W. — APPROVED R.Q.
GREAT FALLS MONTANA — MARCH [illegible]
1305-600-20

PLATE 31



1.
-13" good for surface
-26" good for surface best for use below 6"
26"+ hard lenticular sandstone

2.
-10" good for surface
-52" unsuited for upper 36"
-64" saline alkali shale for use below 36"

3.
-12" good for surface
-28" good for surface best for use below 12"
-80" highly weathered silty shale good, best for use below 12"
120" saline alkali

4.
-16" good for surface
-42" saline and slightly alkaline best for use below 24"
-45" saline alkali best for use below 48" unsuited for top 36"

5.
- 6" good for surface
-12" good for surface best use below 6"
27" very saline best use below 24"
-48" silty/clayey shale saline and alkaline best for use below 48"

6.
- 8" good for surface
-40" good, best use below 6"
-60" saline and alkaline unsuited for surface best use below 36"

7.
-10" good for surface
-36" slowly permeable best for use below 12"
-64" highly saline and alkaline silty shale unsuited for surface best below 36"

8.
- 6" good for surface
-64" soft sandstone best for use below 6"

10.
- 3" good for surface
-14" clay best for use below 6"
-24" weathered clayey shale best for use below 12"
-59" saline alkali clayey shale use below 48"

11.
- 6" good for surface
-20" good for surface best for use below 6"
-33" clayey best use 12".
-60" clayey shale best for use below 12"

12.
- 4" good for surface
-14" clayey best for use below 6"
-60" clayey slow permeable best for use below 12"

13.
- 9" good for surface
-16" good for surface best for use below 6"
-60" weakly consolidated silty shale, good, best for use 12".

14.
-16" good for surface
-60" good for surface, best for use below 6"
High lime below 16"

15.
- 9" good for surface
-18" good for surface, best for use below 6"
-60" silty shale, good, best use below 12"

16.
-21" fair to good for surface
-60" very saline unsuited for surface, best for use below 24"
-120" raw shaley clay very saline and alkaline unsuited for surface place below 60"

17.
- 8" good for surface
-30" good for surface best for use below 12"
-60" saline alkali material unsuited for surface best for use below 36"

18.
-24" good for surface
-44" fair for surface best for use below 6"
-62" soft sandstone good best for use below 6"

19.
-16" good for surface
-25" good for surface best for use below 6"
-31" soft sandstone good best for use below 6"
-120" soft sandstone breaks to med. sand, unsuited for surface, best for use below 24"

20.
- 6" good for surface
-16" fair for surface best for use below 6"
-72" sil. weathered clayey shale best use below 24"
-118" carbonaceous shale and coal - acid could be mixed and placed below 36"

21.
-16" good for surface
-24" silty shale good best for use below 6"
-120" coarse silty shale good, best for use below 12"

22.
- 8" good for surface
-16" good for surface best use below 6"
-24" weathered sandy shale good best for use 6".
-60" sandy shale best for use below 12"

23.
- 8" good for surface
-16" good for surface best for use below 6"
-60" soft sandy shale best for use below 12"

9.
-15" good for surface
-48" silty shale best for use below 12"

Location and Extent of Useable Overburden

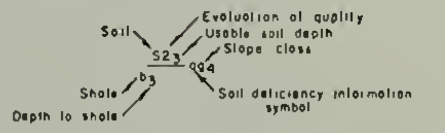
Section 34, T. 3 S., R. 45 E.

Area	Acres	Horizon A (Inches)	A/B (Inches)	B/C (Inches)	C (Inches)	Total (Inches)
NE¼						
A1	2.2	6.0			6.0 (G) 6.0	18.0
A2	2.6	8.0	8.0	48.0	(G)10.0	74.0
A3	16.1**	2.1			(G)12.0	14.1
A4	4.4*	1.5			(Gs)20.0	21.5
A5	7.5	7.0		6.9	(s)19.5	33.4
A6	6.6	6.8	6.8	12.3	(s)10.9	36.8
A7	5.9*	5.0	6.6	(G)18.0		29.6
A8	5.0	8.0	16.0	20.0	(G)89.0	133.0
A9	7.1*			(s) 5.9 (G)11.0		16.9
A10	19.5**	3.5	2.3		(s) 5.1 (G) 5.1	16.0
A11	5.6	7.5	10.4	72.0		89.9
A12	6.6	7.2	7.2	40.0 (G)80.0		134.4
A13	1.3**	4.6	12.0	(G)30.0		46.6
A14	2.1	5.7	6.3	64.0		76.0
A15	5.2	6.2	4.6	7.6 (G)38.5		56.9
A16	1.2*		3.0	(G)50.0		53.0
NW¼						
B1	1.1	6.0	8.0		30.0 (G)80.0	124.0
B2	1.5*	3.2		10.0	(G)10.0	23.2
B3	6.2	5.5	(h)18.9		(G)shp34.0	58.4
B4	4.6		3.9	6.5		10.4
B5	8.4	8.0	10.0	8.0		26.0
B6	14.9	12.0	13.0	(G) 6.0		31.0
SW¼						
C1	.4	6.0	8.0	30.0 (G)80.0		124.0
C2	4.0*	2.7		10.0 (G)10.0		22.7
C3	4.0**	2.2	(h)20.0	(G)shp34.0		56.2
C4	57.6**	2.7	.5	4.7 (G)17.4		25.3
C5	15.6*	1.3	4.3	(G)sh10.0		15.5
C6	4.2	4.8	4.9	(G)12.0		21.7
C7	3.8*	2.8		(G) 6.0		62.8
C8	3.3	8.0	10.0	48.0		64.0
SW¼(Cont.)						
C9	3.4	6.2		3.8		10.0
C10	7.4*	2.2		2.3		4.5
C11	17.7**	0.9	5.6	4.9		11.4
C12	4.9	6.0	4.0			10.0
C13	1.8	6.0		10.0	(Nap)10.0	26.0
C14	4.5	8.0	10.0	48.0		64.0
C15	1.1*	2.2		1.4		3.6
C16	6.7	5.2		(h) 8.6	(NaS)10.0	23.8
C17	5.7	8.8		(NaS) 8.7 (G) 1.5		19.0
C18	2.1*	2.2		(G) 2.5		4.7
C19	1.5	5.3	6.7	(G) 9.3		21.3
C20	1.9*	2.2		2.6		4.8
C21	1.5*	3.4		(G) 5.2		8.6
SE¼						
D1	6.5*	1.4				1.4
D2	1.2*	3.0		6.0		9.0
D3	8.8	6.7		(G) 4.2		10.9
D4	2.7	6.0	14.0	(NaS)46.0		66.0
D5	2.2	6.0		27.7	(G)36.0	69.7
D6	21.1*	0.7	.5	(NaS) 4.4		5.6
D7	19.4*	.5		(G) 9.4		9.9
D8	21.5	7.4	2.5	(G)70.0		79.9
D9	6.7*	1.4				1.4
D10	5.8*	.8	1.2			2.0
D11	4.2*	3.2		(G)57.0		60.2
D12	4.0	8.3	8.8		(Na)46.8	63.9
D13	28.1	4.9	5.1		(G)52.3	62.3
D14	1.1*	3.3		5.8 (G)45.8		54.9
D15	1.3**	6.0		18.5 (G)40.6		65.1
D16	6.6	6.0	6.0	40.0 (G)68.0		120.0
D17	8.5**	5.2		6.9 (G)34.6	(G)25.0	71.7
D18	1.0*			(G)30.0	(G)30.0	60.0
D19	6.1	6.7	14.8	57.2		78.7

Explanation:

*	Topographic and soil limitations most likely will preclude stripping and stockpiling surface material.
**	Topographic and soil limitations will limit stripping part of the area.
(NaS)	Saline-alkali
(s)	Saline moderate to high
(Na)	Sodic
(G)	Material from geologic strata
(p)	Restricted permeability
(h)	Clay
	Horizons, Reconstructed Profile: (A) 0 - 6", (B) 0 - 12", (BC) 6 - 24", (C) 24+

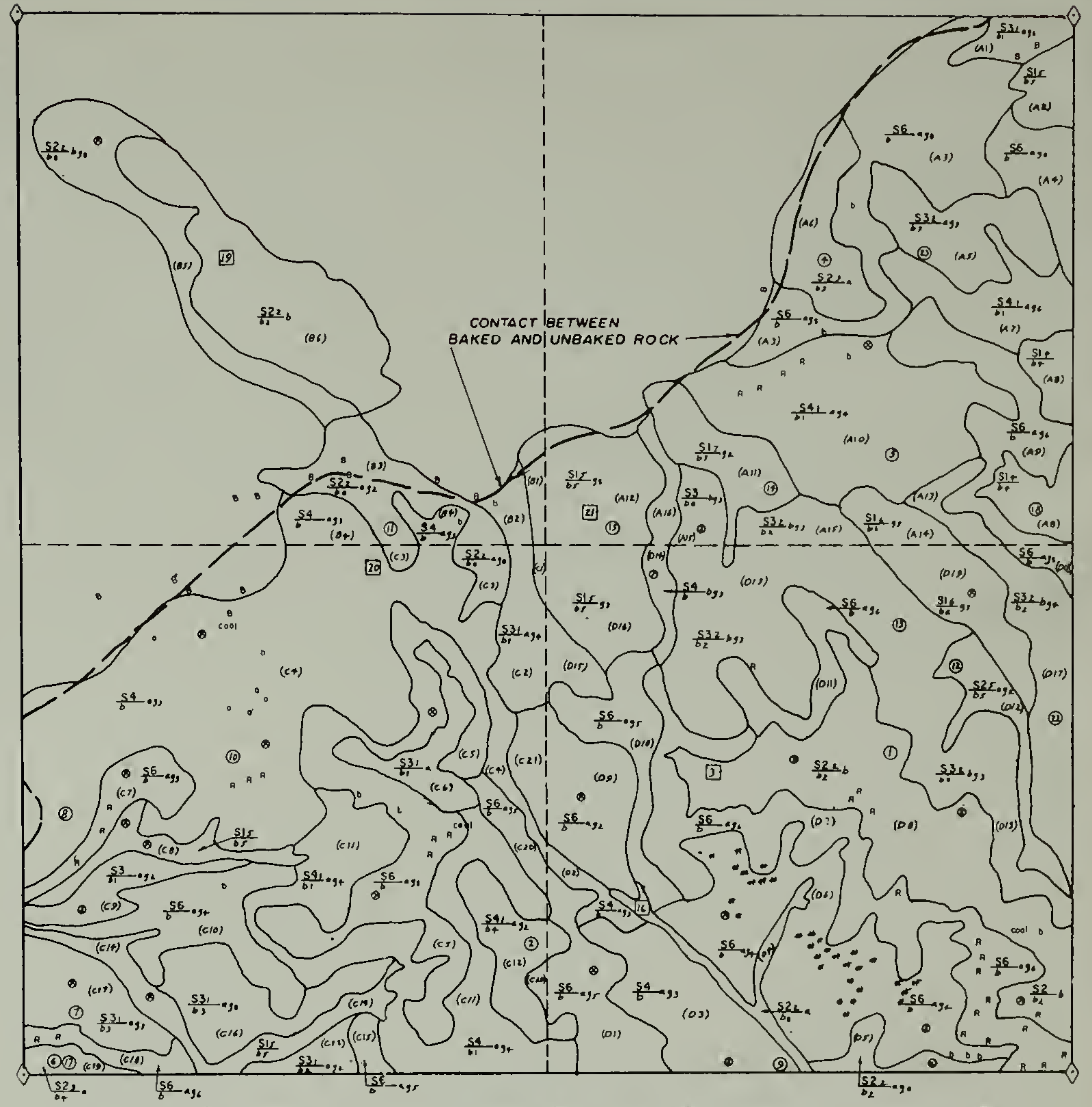
EXPLANATION



INFORMATIVE SYMBOLS

SLOPE		PRINCIPAL SOIL DEFICIENCY			
	0 - 3 Percent	a	Salinity and/or alkalinity	B	Burned rock
g2	3 - 7 Percent	b	Depth to shale	ı	Massive surface rock
g3	7 - 12 Percent	h	Clay	c	Exposed shale
g4	12 - 20 Percent	p	Permeability	∴	Alkaline
g5	20 - 35 Percent	q	Limited moisture retention	✱	Greasewood
g6	35 - 75 Percent	R	Surface rock (large)		
		x	Surface gravel or stone (small)		
		\	Coarse texture		

General or average depth to shale in feet, absence of subscript indicates a depth range 0 to 1 foot



	S1 d 10 b 10-18	S1 d 4-6 b 4-8	S1/g2 d 4-10 b 4-10	S1/g3 d 5-10 b 8-10	S2/s-b-h d 3-5 b 5-10	S2/a-b-h d b 3(g2)5-10	S2/a-b-h d b 3(g3)3-4	S3/a-6-h d 2 b 3	S3/a-b-h-s d b 1-3(g2)1-3	S3/a-h-b d b 2-7(g3)2-7	S3/a-b-R d b 2-3(g4)2-3	S4/a-h-b d 1-2 b 1-2	S4/a-b-h d b 0-1(g3-g4)0-1	S4/a-b-h g 5-6 b 0-1	S6/s-b-n	S6/a-b-h g 2-4 b 0-1	S6/a-b-h g 5-6 b 0-1	Total
Sec. 2-4-45	74.4	3.7	21.0	29.2	16.1	8.4	22.6	4.2		14.7	20.4	3.5	53.7	60.3		13.0	94.4	439.6
Sec. 26-3-45	8.7	48.2	21.6	5.2	26.6	5.4	16.6	36.0	11.7	21.2		14.8	48.1	20.4	29.1	36.2	69.8	413.6
Sec. 34-3-45	5.6	15.4		16.8	47.2	24.8		4.2	19.8	40.8	16.6	4.9	111.7	5.9		56.6	69.1	439.4
Total	88.7	67.3	42.6	51.2	89.9	38.6	39.2	44.4	31.5	76.7	37.0	23.2	213.5	86.6	29.1	105.8	233.3	1298.6

SEC 34, T3S, R45E
POWDER RIVER CO.

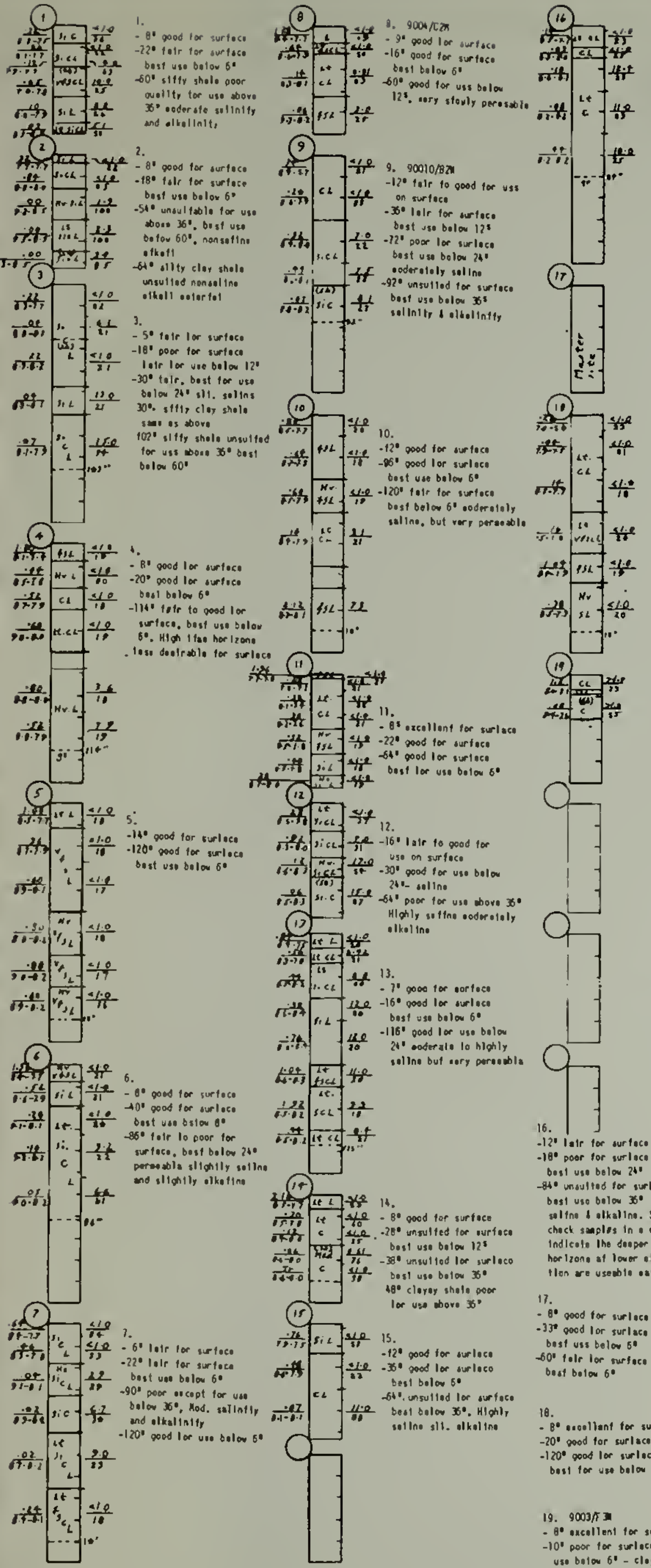
400 0 400 800 1200
SCALE OF FEET

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

DETAILED LAND CLASSIFICATION

OTTER CREEK STUDY SITE
OTTER CREEK COAL FIELD

DESIGNED H. B. WARD SUBMITTED H.B. Ward
DRAWN E. G. H. RECOMMENDED
CHECKED H. B. W. APPROVED B. Q. Gibbs
GREAT FALLS, MONTANA MARCH 1975 1305-600-21



1.
- 8" good for surface
-22" fair for surface best use below 6"
-60" silty shale poor quality for use above 36" moderate salinity and alkalinity

2.
- 8" good for surface
-18" fair for surface best use below 6"
-54" unsuitable for use above 36", best use below 60", nonsaline alkali
-64" silty clay shale unsuited nonsaline alkali material

3.
- 5" fair for surface
-18" poor for surface fair for use below 12"
-30" fair, best for use below 24" sli. saline
30". silty clay shale same as above
102" silty shale unsuited for use above 36" best below 60"

4.
- 8" good for surface
-20" good for surface best below 6"
-114" fair to good for surface, best use below 6". High lime horizons less desirable for surface

5.
-14" good for surface
-120" good for surface best use below 6"

6.
- 8" good for surface
-40" good for surface best use below 8"
-86" fair to poor for surface, best below 24" permeable slightly saline and slightly alkaline

7.
- 6" fair for surface
-22" fair for surface best use below 6"
-90" poor except for use below 36", Mod. salinity and alkalinity
-120" good for use below 6"

8. 9004/C2M
- 9" good for surface
-16" good for surface best below 6"
-60" good for use below 12", very slowly permeable

9. 90010/B2M
-12" fair to good for use on surface
-36" fair for surface best use below 12"
-72" poor for surface best use below 24" moderately saline
-92" unsuited for surface best use below 36" salinity & alkalinity

10.
-12" good for surface
-96" good for surface best use below 6"
-120" fair for surface best below 6" moderately saline, but very permeable

11.
- 8" excellent for surface
-22" good for surface
-64" good for surface best for use below 6"

12.
-16" fair to good for use on surface
-30" good for use below 24"- saline
-64" poor for use above 36" Highly saline moderately alkaline

13.
- 7" good for surface
-16" good for surface best use below 6"
-116" good for use below 24" moderate to highly saline but very permeable

14.
- 8" good for surface
-28" unsuited for surface best use below 12"
-38" unsuited for surface best use below 36"
48" clayey shale poor for use above 36"

15.
-12" good for surface
-36" good for surface best below 6"
-64". unsuited for surface best below 36". Highly saline sli. alkaline

16.
-12" fair for surface
-18" poor for surface best use below 24"
-84" unsuited for surface best use below 36" saline & alkaline. Spot check samples in a gully indicate the deeper horizons at lower elevation are useable material

17.
- 8" good for surface
-33" good for surface but best use below 6"
-60" fair for surface best below 6"

18.
- 8" excellent for surface
-20" good for surface
-120" good for surface best for use below 6"

19. 9003/F3M
- 8" excellent for surface
-10" poor for surface best use below 6" - clay
10". clayey shale poor for surface best use below 6"

Location and Extent of Useable Overburden

Section 2, T. 4 S., R. 45 E.

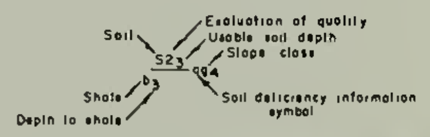
	Area	Acres	A (Inches)	A/B (Inches)	B/C (Inches)	C (Inches)	Total (Inches)
NE¼							
	A1	4.5	5.6	11.2	31.0		47.8
	A2	5.1*	2.5			11.1	13.6
	A3	9.3**		6.7	11.7	(C)12.9	31.3
	A4	2.3*	3.4		(C)18.7		22.1
	A5	2.5	8.0	5.4	40.0		53.4
	A6	3.8*	1.0		20.0		21.0
	A7	9.6**	3.3		13.0		16.3
	A8	3.2	5.1		23.0		28.1
	A9	13.5	2.4	8.4	14.2		25.0
	A10	33.5*	1.5			(G) 1.9	3.4
	A11	5.3	4.8	9.7		(C)36.0	50.5
	A12	2.8	7.4	13.5	52.9		73.8
	A13	7.5	2.2	11.4		(S)50.0	63.6
	A14	1.6**	4.0	6.0	10.0	36.0	56.0
	A15	2.1	8.0	12.0	18.0	(G)12.0	50.0
	A16	1.7*		6.0	10.0	40.0	56.0
	A17	10.6	8.0	14.0	42.0	29.5	93.5
	A18	1.2*		4.0	8.0		12.0
	A19	11.0	8.0	16.0	98.8		122.8
	A20	1.0**	4.0		10.0	(G)20.0	34.0
	A21	2.3*			6.0	8.0	14.0
	A22	1.0*				8.0	8.0
	A23	0.5	8.0	10.0	48.0		66.0
	A24	4.3*		1.3		3.0	4.3
	A25	2.6	6.0		30.0	18.0	54.0
	A26	5.2*	0.9		12.0	(G)36.0	48.9
NW¼							
	B1	0.5	10.0	10.0	72.0		92.0
	B2	3.0*			4.0		4.0
	B3	16.0*			2.1	(GNaS)3.2	5.3
	B4	1.0	6.0	10.0	60.0		76.0
	B5	16.8**	3.4	2.3	5.6	(NaS)14.9	26.2
	B6	13.5*	2.2		5.4	(GNaS)10.8	18.6
	B7	5.2	8.0	10.0	120.0		138.0
	B8	6.6	6.4	7.5	84.5		98.4
	B9	2.1**	4.0		8.0	(G) 8.0	30.0
	B10	3.6	6.0	8.0	72.0		86.0
	B11	9.0**	3.5		12.0	(Ch)24.0	39.5
	B12	2.1*		6.0	18.0	(S)36.0	60.0
NW¼ (Cont.)							
	B13	9.3**	5.5		(G)12.7	(C)30.0	48.2
	B14	2.5	8.0	10.0	60.0		78.0
	B15	5.7	1.7		5.3	(C) 9.6	16.6
	B16	6.6	7.6	10.0	17.3	(Ch)24.0	58.9
	B17	1.8*	4.0	6.0	12.0		22.0
	B18	1.9	10.0	12.0	84.0		106.0
	B19	3.6*	0.9		12.0		12.9
	B20	2.5	8.0	14.0	42.0	(NaS)20.0	84.0
SW¼							
	C1	2.9	10.0	12.0	84.0		106.0
	C2*	9.1		4.0	6.7		33.7
	C3	1.2	6.0		8.0	10.0	24.0
	C4	3.3	7.0	9.0	20.0	(SNa)84.0	120.0
	C5**	3.5	4.0		12.0	(C)20.0	36.0
	C6	2.2	8.0	12.0	80.0		100.0
	C7	2.5	2.9	11.0	36.0		49.9
	C8	10.5	6.9	12.0	96.0		114.9
	C9	10.7	5.1	20.4	122.9	7.2	155.6
SE¼							
	D1*	9.5				0.6	0.6
	D2*	2.0	4.0		8.0	12.0	24.0
	D3	3.2	4.1		4.1	(NaS)72.0	80.2
	D4	3.2	6.5	9.7	84.0		100.2
	D5*	9.5	0.8		8.0		8.8
	D6	0.8	8.0	10.0	60.0		78.0
	D7	1.6	4.0		10.0	40.0	54.0
	D8*	7.0		2.2	7.1		9.3
	D9	3.2	10.0	12.0	84.0		106.0
	D10	3.2	2.4		10.6		13.0
	D11	2.4	2.5	11.5	60.0		74.0
	D12	5.4	5.0		16.0		21.0
	D13	16.7	2.9		6.8	(CNaS)22.0	31.7
	D14	11.7	5.9	5.7	60.0		71.6
	D15	6.7	2.7	2.7	40.0		45.4
	D16	30.2	5.1	20.6	126.9	6.8	159.4
	D17	2.4	6.0	24.0	40.0	60.0	130.0
	D18	18.3	8.0	9.6	100.0	36.0	153.6
	D19**	4.5	4.9		10.0		14.9
	D20	0.6	6.0	18.0	48.0		72.0
	D21*	3.6			6.0		6.0

Explanation:

*	Topographic and soil limitations most likely will preclude stripping and stockpiling surface material.
**	Topographic and soil limitations will limit stripping part of the area.
(NaS)	Saline-alkali
(a)	Saline moderate to high
(Na)	Sodic
(C)	Material from geologic strata
(h)	Clay

Horizons, Reconstructed Profile: (A) 0 - 6", (B) 0 - 12", (BC) 6 - 24", (C) 24"+

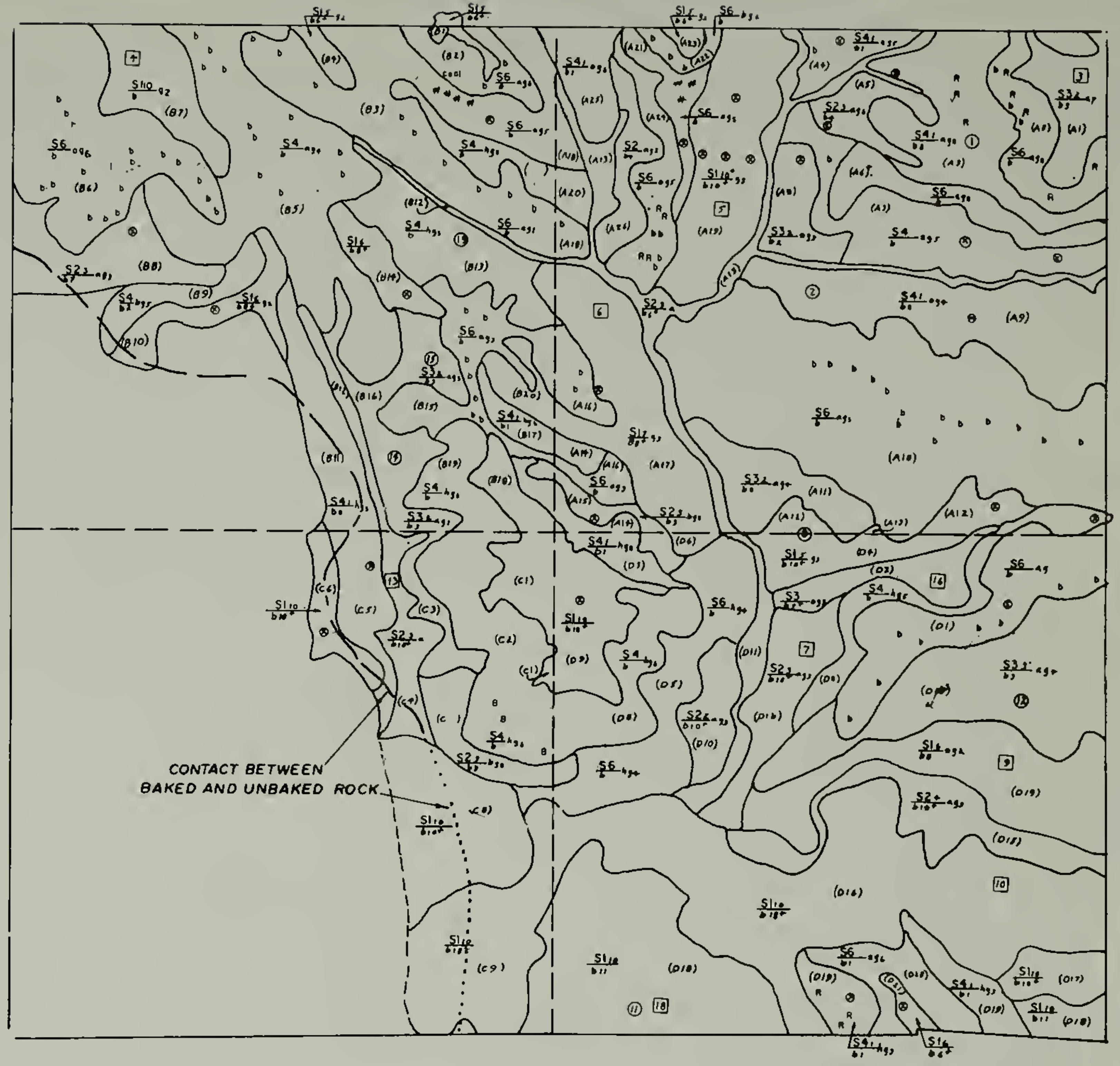
EXPLANATION



INFORMATIVE SYMBOLS

SLOPE	PRINCIPAL SOIL DEFICIENCY	
0 - 3 Percent	a Salinity and/or alkalinity	9 - Burned rock
g2 — 3 - 7 Percent	b depth to shale	r - Massive surface rock
g3 — 7 - 12 Percent	h Clay	c - Exposed shale
g4 — 12 - 20 Percent	p Permeability	- Alkaline
g5 - 20 - 35 Percent	q Limited moisture retention	# - Greasewood
g6 35 - 75 Percent	R Surface rock (large)	
	X Surface gravel or stone (small)	
	V Coarse texture	

General or average depth to shale in feet, absence of subscript indicates a depth range 0 to 1 foot.



	S1 d/10 b/10-18	S1 d/4-6 b/4-8	S1/g d/4-10 b/4-10	S1/g3 d/5-10 b/8-10	S2/a-b-h d/3-5 b/5-10	S2/a-b-h d/3(g2) b/5-10	S2/a-b-h d/3(g3) b/3-4	S3/a-b-h d/2 b/3	S3/a-b-h-s d/1-3(g2) b/1-3	S3/a-h-b d/2-7(g3) b/2-7	S3/a-b-K d/2-3(g4) b/2-3	S4/a-h-b d/1-2 b/1-2	S4/a-b-h d/0-1(g3-g4) b/0-1	S4/a-b-h g/5-6 b/0-1	../a-b-h	S6/a-b.. g/2-4 b/0-1	S6/a-b-h g/5-6 b/0-1	Total
Sec. 2-4-45	74.4	3.7	21.0	29.2	16.1	8.4	22.6	4.2		14.7	20.4	3.5	53.7	60.3		13.0	94.4	439.6
Sec. 28-3-45	8.7	48.2	21.6	5.2	26.8	5.4	18.6	36.0	11.7	21.2		14.8	46.1	20.4	29.1	35.2	69.6	418.6
Sec. 34-3-45	5.8	15.4		18.8	47.2	24.8		4.2	18.8	40.8	18.6	4.9	111.7	5.8		56.8	89.1	438.4
Total	88.7	87.3	42.6	51.2	89.9	38.6	39.2	44.4	31.5	76.7	37.0	23.2	213.5	86.6	29.1	105.6	233.3	1298.6

SEC 2, T4S., R45E
POWDER RIVER CO.

400 0 400 800 1200
SCALE OF FEET

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

DETAILED LAND CLASSIFICATION

OTTER CREEK STUDY SITE
OTTER CREEK COAL FIELD

DESIGNED H. B. WARD SUBMITTED
DRAWN E.B.H. RECOMMENDED
CHECKED H.B.W. APPROVED C.Q. Gibbs

GREAT FALLS, MONTANA FEBRUARY 1975 1305-600-22

PLATE 33

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

SOIL CHEMICAL PROPERTIES

Soil name, sample number, and location (1)	Depth from surface (in.) (2)	Horizon (3)	Soil reaction (water 1:1) (pH) (4)	Organic matter: Carbon (5)	Total nitrogen (%) (6)	Carbon nitrogen ratio (C/N) (7)	Free iron (Fe_2O_3) (%) (8)	Extractible cations (Meq/l): Ca (9)	Mg (10)	Na (11)	K (12)	Cation exchange capacity (NH_4OAc) (ME/100g) (13)	Base saturation (NH_4OAc) (%) (14)	Electrical conductivity ECx10³ (mmhos/cm) (15)	Exchangeable sodium (ESP) (%) (16)	Sodium adsorption ratio (SAR) (17)	Extractible anions (Meq/l): $CO_3^=$ (18)	HCO_3^- (19)	$SO_4^=$ (20)	Cl^- (21)	NO_3
Site 1- 9003 (Midway) 1700' N and 2400' S of SW Cor. Sec. 34, T3S, R.45E.	0-3	A1	7.3	1.9				8.0	2.1	0.4	0.6	12.1		1.0	1.7	0.2					
	3-6	AC	7.4	1.2				5.5	2.1	1.0	0.3	15.4		0.7	2.3	0.5					
	6-12	C1Ca	7.5	0.6				7.8	4.1	5.7	0.6	11.1		1.5	3.6	2.3					
	12-19	C2	7.6	0.4				24.2	32.8	28.9	0.6	8.5		5.9	7.1	5.4		1.2	800	0.9	0.11
	19-38	C3	7.6	0.1				22.9	40.7	37.1	0.9	8.3		6.9	4.5	6.9		1.0	98.0	1.2	0.06
	38-60	C4	7.3	0.1				22.8	35.8	37.3	0.8	9.0		6.8	9.3	6.9		1.3	91.0	1.3	0.09
Site 3 9002 (Thurlow) 2200'S. and 800'W of NE Corner Sec. 34, T.3S, R.45E.	0-3	A1	7.3	2.1				6.5	1.7	0.6	0.6	25.0		0.9	1.0	0.3					
	3-13	B2t	7.3	1.2				5.2	2.1	1.0	0.2	24.7		0.8	1.5	0.5					
	13-18	B3Ca	7.4	0.9				4.3	3.4	1.5	0.2	21.6		0.8	2.4	0.8					
	18-25	C1Ca	7.6	0.6				12.1	25.2	15.9	0.5	14.4		3.9	3.3	3.7					
	25-40	C2Ca	8.0	0.4				21.2	138.1	58.9	1.0	13.0		12.1	8.6	6.6		1.2	[illegible]	43	0.1
	40-52	C3	7.9	0.4				26.6	114.9	53.6	1.1	22.8?		11.5	4.9	6.7		1.0	184.5	2.1	0.4
	52-60	C4Cs	7.9	0.1				28.8	81.2	49.0	1.2	18.6		9.8	3.5	6.6		1.1	152.0	1.1	0.2

Remarks

(Instructions on reverse) Form 7310-20 (August 1973)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

SOIL PHYSICAL PROPERTIES

Soil name, sample number, and location (1)	Depth from surface (in.) (2)	Horizon (3)	Particle size distribution in millimeters (Percentage): Sand: Very coarse (2-1) (4)	Coarse (1-0.5) (5)	Medium (0.5-0.25) (6)	Fine (0.25-0.1) (7)	Very fine (0.1-0.05) (8)	Total (9)	Silt (0.05-0.002) (10)	Clay (0.002) (11)	Textural class (12)	Moisture held at (Percentage): 1/10 bar (13)	1/3 bar (14)	15 bars (15)	Available water (16)	Bulk density (17)
Site 2 - 9001 (Haverson) 700' N nd 600" E of SW Corner Sec. 2, T. 4 S., R. 45 E.	0-2	A1	1.1	1.0	0.8	5.6	13.8	22.3	56.9	20.8	SiL	33.5	22.7	11.2		
	2-8	AC	0.4	0.4	0.5	5.4	13.6	20.3	57.0	22.7	SiL	30.9	19.1	9.3		1.34
	8-33	C1	0.2	0.3	0.4	6.2	22.2	29.3	51.0	19.7	SiL	26.3	15.5	8.0		1.24
	33-49	C2	1.6	2.7	3.5	17.5	21.8	47.0	34.7	18.3	L	27.1	14.3	7.8		1.30
	49-60	C3	4.2	4.1	3.9	26.6	21.8	60.6	26.9	12.5	VFSL	15.5	10.5	5.7		
Site 6 - 9004 (McRae) 1000' E and 300' S of NW Corner Sec. 2, T. 4 S., R. 45 E.	0-3	A1	2.3	1.2	2.8	26.0	21.9	54.2	29.5	16.3	VFSL	21.0	14.2	9.0		
	3-6	B2	1.4	1.3	2.3	26.9	20.4	52.3	29.0	18.7	VFSL	20.2	14.4	9.5		1.41
	6-20	B3Ca	0.6	0.3	1.0	10.8	27.8	40.5	35.2	24.3	L	24.4	17.7	9.5		1.41
	20-27	C1Ca	4.0	0.6	1.6	11.3	18.8	36.3	38.3	25.4	L	23.9	17.7	8.7		
	27-40	C2	0.5	0.3	2.2	16.5	16.0	35.5	40.6	23.9	L	20.2	14.2	7.8		

Remarks

(Instructions on reverse) Form 7310-19 (August 1973)

28-19
5/68

Master Sites

MISSOURI SOURIS PROJECTS OFFICE
BUREAU OF RECLAMATION
BISMARCK, NORTH DAKOTA
SOIL ANALYSIS DATA SHEET

Date Received 11/13/74
Date Reported

AREA: Otter Creek Mont. INVESTIGATOR: Harold Ward SECTION: 34 TOWNSHIP: [illegible] RANGE: 45E.

Lab Number	Master Site Number	Depth in Inches	Field Texture	% Sand	% Silt	% 2µ Clay	Lab Texture	Moisture retention (% water) 1/10 Bar Tension	15 Bar Tension	Frac Hyd Cond in/hr	in/hr	in/hr	Sat Vol (ml)	ECe ×10³	pH 1:5	pH Paste	Bulk Density g/cc
W324	1	0-3	CL	37.2	34.1	28.7	CL		19.2	0.64	0.96		25	0.16	7.9	7.3	
325		3-6	SiCL	11.5	48.5	40.0	SiCL		13.7	1.00	1.04		23	0.16	7.7	7.4	
326		6-12	CL	4.0	64.0	32.0	SiCL		10.9	0.30	0.30		25	0.21	7.7	7.5	
327		12-19	SiC	3.2	65.9	30.9	SiCL		10.4	0.14	0.18		27	1.2	7.6	7.6	
328		19-38	Clay Shale	2.5	72.8	24.7	SiL		9.7	0.03	0.03		27	1.1	7.8	7.6	
329		38-60	Silty Shale	3.7	70.4	25.9	SiL		10.7	0.14	0.14		30	[illegible]	7.8	7.3	
330	3	0-3	SiC	14.5	43.6	41.9	SiC		15.9	0.40	0.20		24	0.16	7.6	7.3	
331		3-13	C	13.7	40.6	45.7	SiC		15.3	0.44	0.40		22	0.16	7.5	7.3	
332		13-18	SiC	19.4	43.6	37.0	SiCL		13.7	0.32	0.36		23	0.16	7.8	7.4	
333		18-25	Hv. SiCL	28.2	46.9	24.9	L		9.2	0.44	0.40		19	0.65	7.9	7.6	
334		25-40	SiCL	25.7	49.3	25.0	L		10.0	0.48	0.44		20	1.49	8.2	8.0	
335		40-52	Hv. SiL	16.7	57.2	26.1	SiL		10.9	0.22	0.24		21	1.40	8.2	7.9	
336		52-60	C	11.8	55.8	32.4	SiCL		15.0	0.18	0.18		21	1.90	8.1	7.9	
Screenable tests and PSA on #4																	
337	4	0-3	Lf SiL	41.9	45.1	13.0	L		7.3	0.32	1.04		13	0.16	8.0		
338		3-8	SiL	32.0	49.6	18.4	L		8.6	1.60	0.22		20	0.16	8.1		1.29
339		8-17	SiL	12.8	67.2	20.0	SiL		7.1	0.22	0.22		18	0.16	8.4		1.42
340		17-36	SiL	7.1	79.4	13.5	SiL		5.0	0.18	0.18		19	1.10	8.3		1.45
341		36-60	FSL	66.7	26.0	7.3	VFSL		3.6	0.72	0.80		17	1.63	8.7		

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

SOIL CHEMICAL PROPERTIES

Soil name, sample number, and location (1)	Depth from surface (in.) (2)	Horizon (3)	Soil reaction (water 1:1) (pH) (4)	Organic matter: Carbon (5)	Total nitrogen (%) (6)	Carbon nitrogen ratio (C/N) (7)	Free iron (Fe_2O_3) (%) (8)	Extractible cations (Meq/l): Ca (9)	Mg (10)	Na (11)	K (12)	Cation exchange capacity (NH_4OAc) (ME/100g) (13)	Base saturation (NH_4OAc) (%) (14)	Electrical conductivity ECx10³ (mmhos/cm) (15)	Exchangeable sodium (ESP) (%) (16)	Sodium adsorption ratio (SAR) (17)	Extractible anions (Meq/l): $CO_3^=$ (18)	HCO_3^- (19)	$SO_4^=$ (20)	Cl^- (21)
Site 2 9001 Haverson 700'N. and 600'E of SW Corner. Sec. 2, T.4 S., R45E.	0-2	A1	7.3	2.5				6.6	1.1	0.5	2.0	22.8		0.9	2.6	0.3				
	2-8	AC	7.5	1.2				5.7	1.4	0.8	1.3	16.1		0.8	2.4	0.4				
	8-33	C1	7.6	1.0				5.1	1.9	1.7	0.5	14.6		0.8	2.3	0.9				
	33-49	C2	7.5	0.9				5.5	1.4	1.3	0.5	14.4		0.8	2.7	0.7				
	49-60	C3	7.6	0.5				6.8	1.1	1.3	0.6	9.2		0.9	3.0	0.7				
Site 6 9004 McRae 1000'E. and 300'S. of NW Corner Sec. 2, T. 4 S., R45E.	0-3	A1	7.3	1.6				6.5	0.8	0.7	0.7	15.3		0.7	1.1	0.4				
	3-6	B2	7.2	1.2				7.0	0.8	0.5	0.3	16.7		0.7	0.5	0.3				
	6-20	B3Ca	7.6	0.7				6.2	1.2	0.5	0.2	14.9		0.7	1.1	0.3				
	20-27	C1Ca	7.8	0.6				3.8	[illegible]	0.6	0.2	14.7		0.6	1.2	0.3				
	27-40	C2	7.9	0.1				1.0	24	3.6	0.1	13.9		0.7	4.3	2.7				

Remarks

(Instructions on reverse) Form 7310-20 (August 1973)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

SOIL PHYSICAL PROPERTIES

Soil name, sample number, and location (1)	Depth from surface (in.) (2)	Horizon (3)	Particle size distribution in millimeters (Percentage): Sand: Very coarse (2-1) (4)	Coarse (1-0.5) (5)	Medium (0.5-0.25) (6)	Fine (0.25-0.1) (7)	Very fine (0.1-0.05) (8)	Total (9)	Silt (0.05-0.002) (10)	Clay (0.002) (11)	Textural class (12)	Moisture held at (Percentage): 1/10 bar (13)	1/3 bar (14)	15 bars (15)	Available water (16)	Bulk density (17)
Site 1 - 9003 (Midway) 1700' N and 2400' E of SW Corner Sec. 34, T. 3 S., R. 45 E.	0-3	A1	6.2	3.9	1.9	9.1	16.1	37.2	34.1	28.7	CL	23.5	19.3	10.2		
	3-6	AC	1.0	1.1	0.5	2.7	6.2	11.5	48.5	40.0	SiCL	26.5	23.2	13.7		1.41
	6-12	C1Ca	0.5	0.7	0.4	1.1	1.3	4.0	64.0	32.0	SiCL	28.8	25.3	10.9		1.38
	12-19	C2	0.4	0.9	0.6	0.9	0.4	3.2	65.9	30.9	SiCL	27.9	25.1	10.6		
	19-38	C3	0.3	0.7	0.5	0.5	0.5	2.5	72.8	24.7	SiL	29.0	25.2	9.7		
	38-60	C4	0.3	0.6	0.4	1.1	1.3	3.7	70.4	25.9	SiL	28.4	25.6	10.7		
Site 3 - 9002 (Thurlow) 2200' S and 800' W of NE Corner Sec. 34, T. 3 N., R. 45 E.	0-3	A1	1.5	1.0	0.7	3.3	8.0	14.5	43.6	41.9	SiC	32.2	28.4	15.9		1.31
	3-13	B2t	0.6	0.6	0.6	2.6	9.3	13.7	40.6	45.7	SiC	40.1	25.1	15.3		1.41
	13-18	B3Ca	0.4	0.5	0.7	3.5	14.3	19.4	43.6	47.0	SiC	27.4	23.8	13.4		1.24
	18-25	C1Ca	0.2	0.3	0.5	4.7	22.5	28.2	46.9	24.9	L	25.3	20.1	9.2		1.37
	25-40	C2Ca	0.1	0.3	0.8	3.9	20.6	25.7	49.3	25.0	L	27.4	21.7	10.0		
	40-52	C3	0.1	0.1	0.3	1.8	14.4	16.7	57.2	26.1	SiL	30.0	23.4	10.9		
	52-60	C4Cs	0.0	0.2	0.1	0.9	10.6	11.8	55.8	32.4	SiCL	31.7	23.8	15.0		

Remarks

(Instructions on reverse) Form 7310-19 (August 1973)

28-19
5/68

Master Sites

MISSOURI SOURIS PROJECTS OFFICE
BUREAU OF RECLAMATION
BISMARCK, NORTH DAKOTA
SOIL ANALYSIS DATA SHEET

Date Received 11/13/74
Date Reported

AREA: Otter Creek Mont. INVESTIGATOR: Harold Ward SECTION: 26 TOWNSHIP: [illegible] RANGE: 45E.

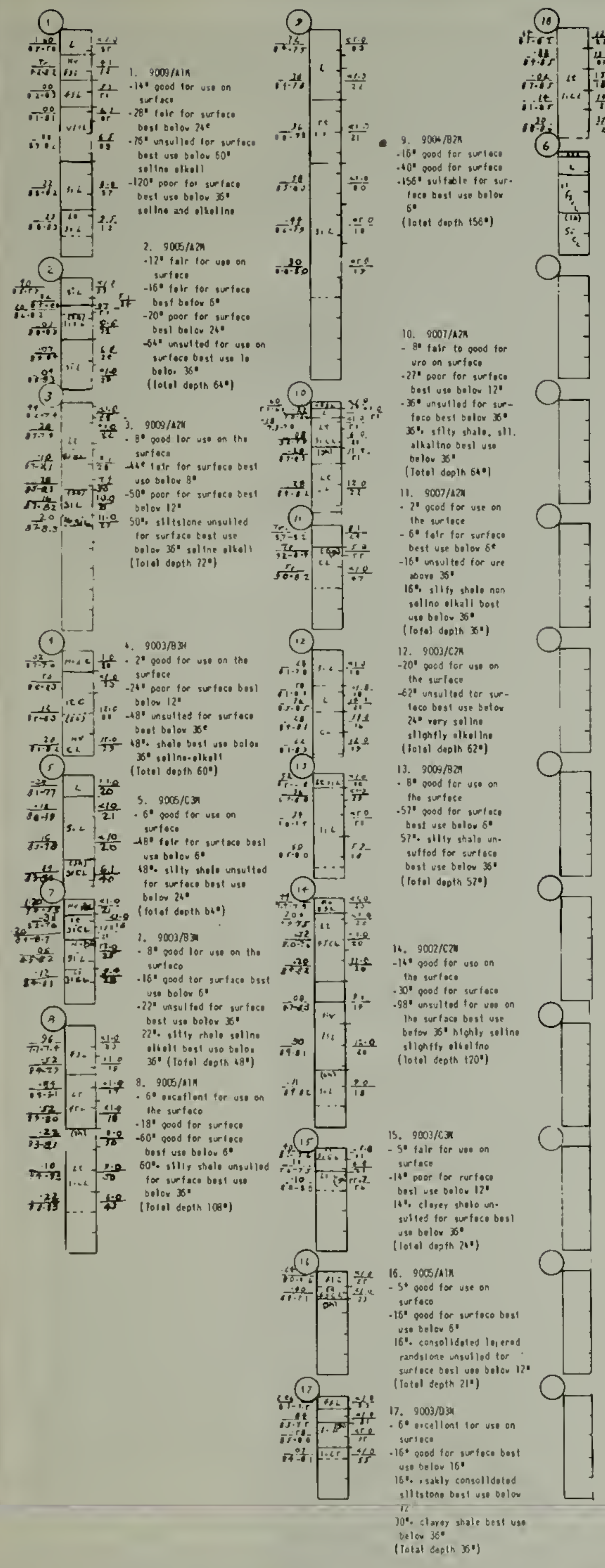
Lab Number	Master Site Number	Depth in Inches	Field Texture	% Sand	% Silt	% 2µ Clay	Lab Texture	Moisture retention (% water) 1/10 Bar Tension	15 Bar Tension	Frac Hyd Cond in/hr	in/hr	in/hr	Sat Vol (ml)	ECe ×10³	pH 1:5	pH Paste	Bulk Density g/cc
W352	5	0-3	L	33.7	49.0	17.1	L		8.1	1.24	1.60		19	0.16	8.0		
353		3-10	SiL	20.5	53.7	25.8	SiL		9.4	0.18	0.24		20	0.16	8.1		1.45
354		10-20	SiL	19.4	54.5	26.1	SiL		9.1	0.24	0.24		21	0.16	8.3		1.65
355		20-34	Hv. SiL	24.5	53.5	22.0	SiL		7.7	0.30	0.32		20	0.20	8.6		1.59
356		34-60	SiCL	3.4	62.9	33.7	SiCL		13.4	0.18	0.20		37	1.29	8.1		
Screenable tests and PSA on #5																	

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

OTTER CREEK STUDY SITE
OTTER CREEK COAL FIELD

MASTER SITE DATA

DRAWN H.B.W. SUBMITTED
TRACED RECOMMENDED
CHECKED H.B.W. APPROVED Phil R. Gibbs
BILLINGS, MONTANA JULY, 1975 1305-600-34



1. 9009/A1M
- 14" good for use on surface
- 28" fair for surface best below 24"
- 76" unsuited for surface best use below 60" saline alkali
- 120" poor for surface best use below 36" saline and alkaline

2. 9005/A2M
- 12" fair for use on surface
- 16" fair for surface best below 6"
- 20" poor for surface best below 24"
- 64" unsuited for use on surface best use is below 36"
(Total depth 64")

3. 9009/A2M
- 8" good for use on the surface
- 44" fair for surface best use below 8"
- 50" poor for surface best below 12"
50"+ siltstone unsuited for surface best use below 36" saline alkali
(Total depth 72")

4. 9003/B3M
- 2" good for use on the surface
- 24" poor for surface best below 12"
- 48" unsuited for surface best below 36"
48"+ shale best use below 36" saline-alkali
(Total depth 60")

5. 9005/C3M
- 6" good for use on surface
- 48" fair for surface best use below 6"
48"+ silty shale unsuited for surface best use below 24"
(Total depth 64")

7. 9003/B3M
- 8" good for use on the surface
- 16" good for surface best use below 6"
- 22" unsuited for surface best use below 36"
22"+ silty shale saline alkali best use below 36" (Total depth 48")

8. 9005/A1M
- 6" excellent for use on the surface
- 18" good for surface
- 60" good for surface best use below 6"
60"+ silty shale unsuited for surface best use below 36"
(Total depth 108")

9. 9004/B2M
- 16" good for surface
- 40" good for surface
- 156" suitable for surface best use below 6"
(Total depth 156")

10. 9007/A2M
- 8" fair to good for use on surface
- 27" poor for surface best use below 12"
- 36" unsuited for surface best below 36"
36"+ silty shale, sl. alkaline best use below 36"
(Total depth 64")

11. 9007/A2M
- 2" good for use on the surface
- 6" fair for surface best use below 6"
- 16" unsuited for use above 36"
16"+ silty shale non saline alkali best use below 36"
(Total depth 36")

12. 9003/C2M
- 20" good for use on the surface
- 62" unsuited for surface best use below 24" very saline slightly alkaline
(Total depth 62")

13. 9009/B2M
- 8" good for use on the surface
- 57" good for surface best use below 6"
57"+ silty shale unsuited for surface best use below 36"
(Total depth 57")

14. 9002/C2N
- 14" good for use on the surface
- 30" good for surface
- 98" unsuited for use on the surface best use below 36" highly saline slightly alkaline
(Total depth 120")

15. 9003/C3M
- 5" fair for use on surface
- 14" poor for surface best use below 12"
14"+ clayey shale unsuited for surface best use below 36"
(Total depth 24")

16. 9005/A1M
- 5" good for use on surface
- 16" good for surface best use below 6"
16"+ consolidated layered sandstone unsuited for surface best use below 12"
(Total depth 21")

17. 9003/D3M
- 6" excellent for use on surface
- 16" good for surface best use below 16"
16"+ weakly consolidated siltstone best use below 12"
30"+ clayey shale best use below 36"
(Total depth 36")

18. 9009/A1M
- 64" Entire profile is saline alkali and should be placed below 60" in a reconstructed profile should not be mixed with soil used in upper 60"

6. 9007/A2M
- 4" fair for use on the surface
- 14" poor for surface best use below 6"
- 30" poor for surface best use below 12"
- 36" unsuited for surface best use below 36"
36"+ shale unsuited for surface best use below 36"
(Total depth 64")

Symbol	Acres	%	Name
01/A1M			9001-Medium loamy soils, 0 to 3 percent slope, stable erosion
02/A1N	5.6	2	9002-Moderately fine loamy soils, 0 to 3 percent slope, stable erosion
02/B2N			9002-Moderately fine loamy soils, 3 to 7 percent slope, slight erosion
02/C2N	5.2	1	9002-Moderately fine loamy soils, 7 to 12 percent slope, slight erosion
02/C3N			9002-Moderately fine loamy soils, 7 to 12 percent slope, moderate erosion
03/B2N	12.0	3	9003-Moderately fine loamy soils, 3 to 7 percent slope, slight erosion
03/B3H	13.3	4	9003-Fine clayey soils, 3 to 7 percent slope, moderate erosion
03/C2M			9003-Medium loamy soils, 7 to 12 percent slope, moderate erosion
03/C2N			9003-Moderate fine loamy soils, 7 to 12 percent slope, moderate erosion
03/C3N	4.8	1	9003-Moderately fine loamy soils, 7 to 12 percent slope, moderate erosion
03/C4N	7.4	2	9003-Moderately fine loamy soils, 7 to 12 percent slope, severe erosion
03/D3N	15.8	4	9003-Moderately fine loamy soils, 12 to 20 percent slope, moderate erosion
03/D4N	2.2	1	9003-Moderately fine loamy soils, 12 to 20 percent slope, severe erosion
03/E3N	17.1	5	9003-Moderately fine loamy soils, 20 to 35 percent slope, moderate erosion
03/E4N	19.9	6	9003-Moderately fine loamy soils, 20 to 35 percent slope, severe erosion
03/F3N			9003-Moderately fine loamy soils, 35 to 75 percent slope, moderate erosion
03/F4N	37.4	10	9003-Moderately fine loamy soils, 35 to 75 percent slope, severe erosion
03S/B3M	20.7	6	9003S-Stony medium loamy soils, 3 to 7 percent slope, moderate erosion
03S/B4M	5.2	1	9003S-Stony medium loamy soils, 3 to 7 percent slope, severe erosion
03S/C2M	21.1	6	9003S-Stony medium loamy soils, 7 to 12 percent slope, slight erosion
04/A1M	0.7		9004-Medium loamy soils, 0 to 3 percent slope, stable erosion
04/B2M	11.0	3	9004-Medium loamy soils, 3 to 7 percent slope, slight erosion
04/C2M	2.7	1	9004-Medium loamy soils, 7 to 12 percent slope, slight erosion
05/A1M	5.0	1	9005-Medium loamy soils, 0 to 3 percent slope, stable erosion
05/A2M	30.3	8	9005-Medium loamy soils, 0 to 3 percent slope, slight erosion
05/C3M	22.5	7	9005-Medium loamy soils, 7 to 12 percent slope, moderate erosion
06/A2M	2.6	1	9006-Medium loamy soils, 0 to 3 percent slope, slight erosion
06/B2M	9.4	3	9006-Medium loamy soils, 0 to 3 percent slope, slight erosion
07/A2N	36.9	10	9007-Moderately fine loamy soils, 0 to 3 percent slope, slight erosion
07/B2N	10.0	4	9007-Moderately fine loamy soils, 3 to 7 percent slope, slight erosion
08/A1M	3.9	1	9008-Medium loamy soils, 0 to 3 percent slope, stable erosion
08/B1M	1.0		9008-Medium loamy soils, 3 to 7 percent slope, stable erosion
08/E3N			9008-Moderately fine loamy soils, 20 to 35 percent slope, moderate erosion
09/A1M	13.7	4	9009-Medium loamy soils, 0 to 3 percent slope, stable erosion
09/B2M	17.6	5	9009-Medium loamy soils, 3 to 7 percent slope, slight erosion
010/B2N			90010-Moderately fine loamy soils, 3 to 7 percent slope, slight erosion
010/C4N			90010-Moderately fine loamy soils, 7 to 12 percent slope, severe erosion

EXPLANATION

SOIL PROFILE NOTES
PROFILE REPRESENTS 5' DEPTH
③ SOIL PROFILE NUMBER

C . . . 28 . . . 28 EC mmhos/cm
24 --- 24 Settling Volume (pH 1:5 Soil-Water Suspension)
65/84-81 L.I.C --- 65 Hydraulic Conductivity in/hr (Disturbed Samples)
------ 8.4 pH 1:5 Soil-Water Suspension
8.1 pH Soil-CaCl₂ Suspension
Gr

SOIL PROFILE SYMBOLS

Cb	Cobble
Gr	Gravel
S	Sand
LS	Loamy Sand
SL	Sandy Loam
L	Loam
SiL	Silt Loam
SCL	Sandy Clay Loam
CL	Clay Loam
SiCL	Silty Clay Loam
SC	Sandy Clay
C	Clay
SiC	Silty Clay
Sh	Shale
Ss	Sandstone
F	Fine
Li	Light
M	Medium
Hv	Heavy

$$\text{Slope} \rightarrow \frac{\overset{\text{Series}}{03}}{0\,3\,N} \leftarrow \begin{matrix}\text{Textural group}\\ \text{Erosion class}\end{matrix}$$

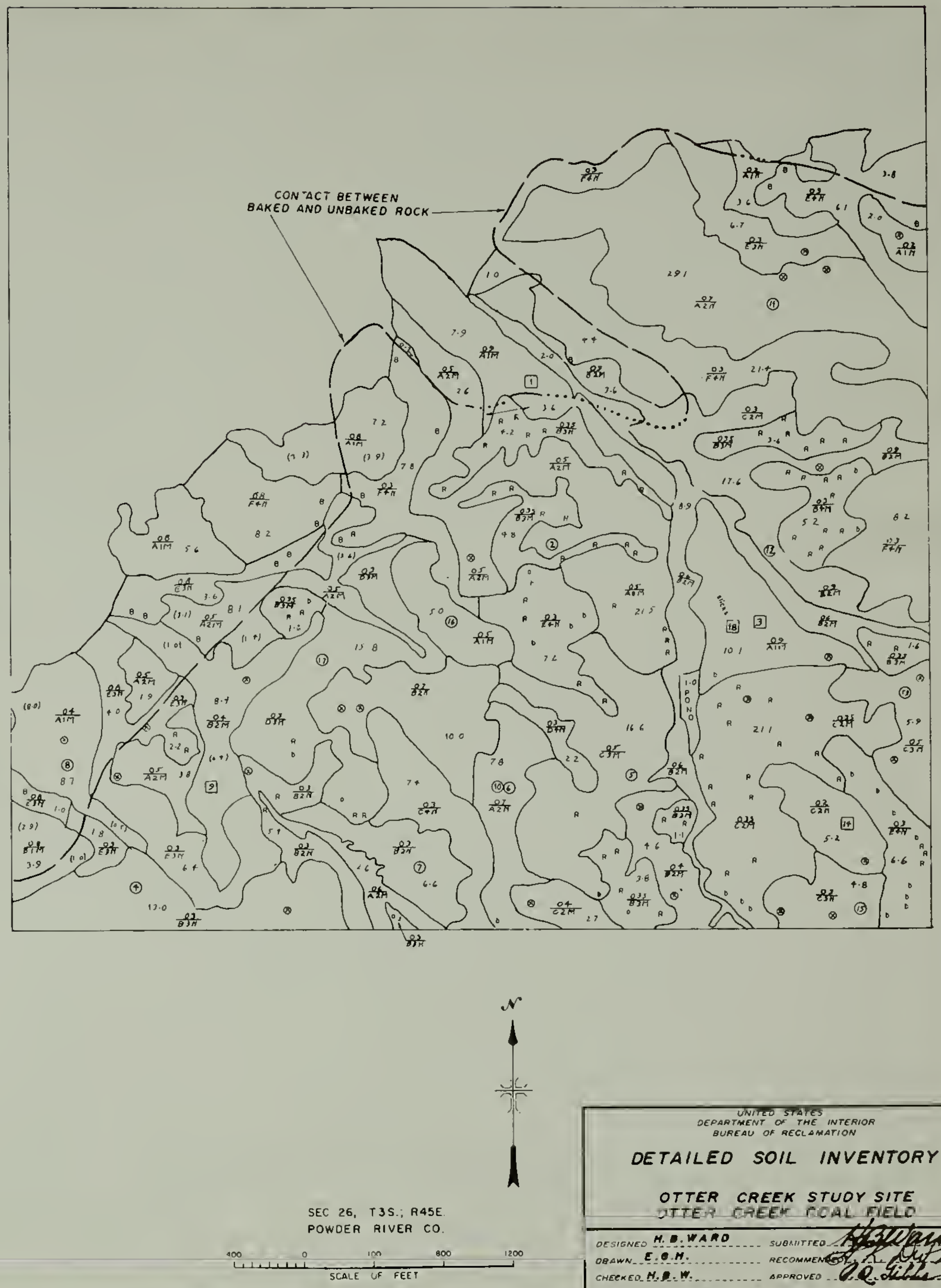
Series Name 9001 through 90011

SLOPE CLASS	EROSION CLASS
A-- 0 - 3 Percent	1 ----Stable
B-- 3 - 7 Percent	2 ----Slight
C-- 7 - 12 Percent	3 --Moderate
D--12-20 Percent	4 ----Severe
E--20-35 Percent	5 --- Critical
F--35-75 Percent	

TEXTURAL GROUP

V	Sand Loamy Sand	Coarse	Sandy
I	Sandy Loam Fine Sandy Loam	Moderately Coarse	Loamy
M	Very Fine Sandy Loam Loam Silt Loam	Medium	Loamy
N	Sandy Clay Loam Clay Loam Silty Clay Loam	Moderately Fine	Loamy
H	Sandy Clay Silty Clay Li, M & H Clay	Fine	Clayey

INFORMATIVE SYMBOLS
- B - Baked rock exposed
- R - Massive outcrop rock
- o - Saline
- b - Shale exposed
- # - Greare wood
- ⊗ - Check hole



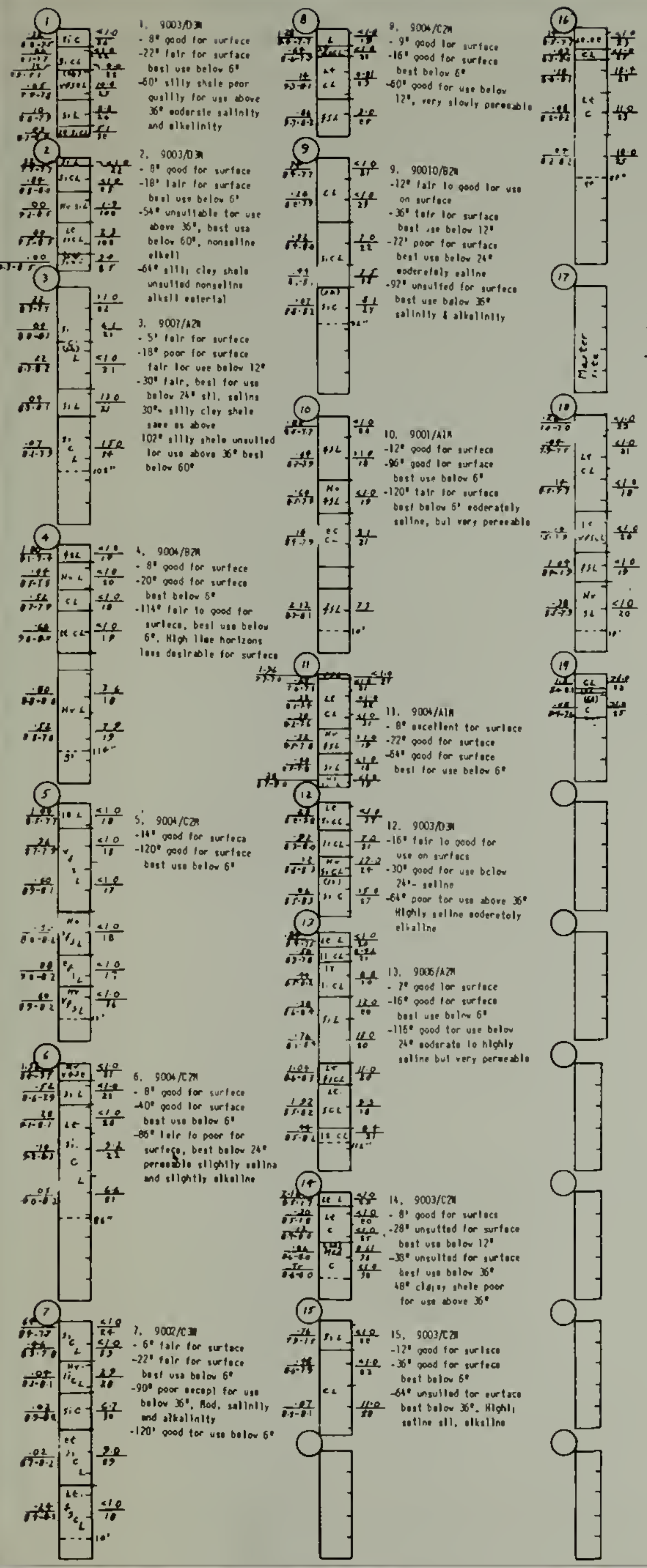
SEC 26, T3S.; R45E.
POWDER RIVER CO.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

DETAILED SOIL INVENTORY

OTTER CREEK STUDY SITE
OTTER CREEK COAL FIELD

DESIGNED H. B. WARD SUBMITTED H. B. Ward
DRAWN E. G. H. RECOMMENDED
CHECKED H. B. W. APPROVED
GREAT FALLS, MONTANA FEBRUARY 1975 1305-600-23



1. 9003/D3N
- 8" good for surface
-22" fair for surface best use below 6"
-60" silty shale poor quality for use above 36" moderate salinity and alkalinity

2. 9003/D3N
- 8" good for surface
-18" fair for surface best use below 6"
-54" unsuitable for use above 36", best use below 60", nonsaline alkali
-64" silty clay shale unsuited nonsaline alkali material

3. 9007/A2N
- 5" fair for surface
-18" poor for surface fair for use below 12"
-30" fair, best for use below 24" sil. saline
30"- silty clay shale same as above
102" silty shale unsuited for use above 36" best below 60"

4. 9004/B2M
- 8" good for surface
-20" good for surface best below 6"
-114" fair to good for surface, best use below 6". High lime horizons less desirable for surface

5. 9004/C2M
-14" good for surface
-120" good for surface best use below 6"

6. 9004/C2M
- 8" good for surface
-40" good for surface best use below 6"
-86" fair to poor for surface, best below 24" permeable slightly saline and slightly alkaline

7. 9002/C3N
- 6" fair for surface
-22" fair for surface best use below 6"
-90" poor except for use below 36", Mod. salinity and alkalinity
-120" good for use below 6"

8. 9004/C2M
- 9" good for surface
-16" good for surface best below 6"
-60" good for use below 12", very slowly permeable

9. 90010/B2N
-12" fair to good for use on surface
-36" fair for surface best use below 12"
-72" poor for surface best use below 24" moderately saline
-92" unsuited for surface best use below 36" salinity & alkalinity

10. 9001/A1M
-12" good for surface
-96" good for surface best use below 6"
-120" fair for surface best below 6" moderately saline, but very permeable

11. 9004/A1M
- 8" excellent for surface
-72" good for surface
-64" good for surface best for use below 6"

12. 9003/D3N
-16" fair to good for use on surface
-30" good for use below 24"- saline
-64" poor for use above 36" Highly saline moderately alkaline

13. 9006/A2M
- 7" good for surface
-16" good for surface best use below 6"
-116" good for use below 24" moderate to highly saline but very permeable

14. 9003/C2M
- 8" good for surface
-28" unsuited for surface best use below 12"
-38" unsuited for surface best use below 36"
48" clayey shale poor for use above 36"

15. 9003/C2N
-12" good for surface
-36" good for surface best below 6"
-64" unsuited for surface best below 36". Highly saline all. alkaline

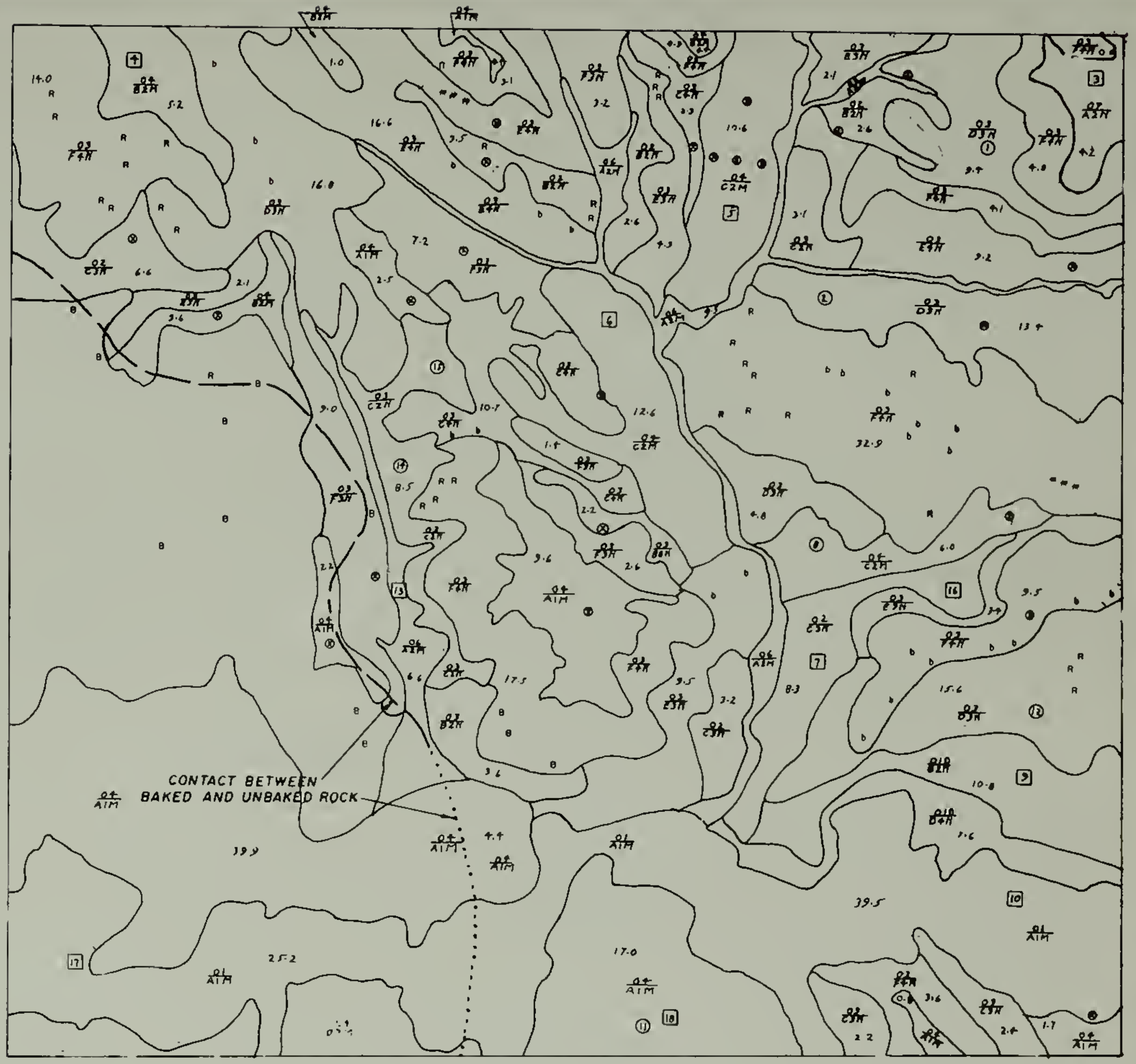
16. 9002/C3N
-12" fair for surface
-18" poor for surface best use below 24"
-84" unsuited for surface best use below 36" saline & alkaline. Spot check samples in a gully indicate the deeper horizons at lower elevation are usable material

17. 9001/A1M
- 8" good for surface
-33" good for surface but best use below 6"
-60" fair for surface best below 6"

18. 9004/A1M
- 8" excellent for surface
-20" good for surface
-120" good for surface best for use below 6"

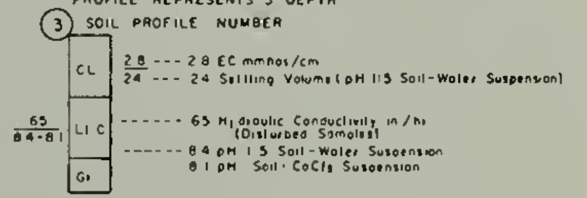
19. 9003/F3N
- 8" excellent for surface
-10" poor for surface best use below 6" - clay
10"- clayey shale poor for surface best use below 6"

Symbol	Acres	%	Name		
01/A1M	35.9	9	9001-Medium loamy soils,	0 to 3 percent slope,	stable erosion
02/A1N			9002-Moderately fine loamy soils,	0 to 3 percent slope,	stable erosion
02/B2N	5.2	1	9002-Moderately fine loamy soils,	3 to 7 percent slope,	slight erosion
02/C2N			9002-Moderately fine loamy soils,	7 to 12 percent slope,	slight erosion
02/C3N	18.1	4	9002-Moderately fine loamy soils,	7 to 12 percent slope,	moderate erosion
03/B2N	9.3	2	9003-Moderately fine loamy soils,	3 to 7 percent slope,	slight erosion
03/B3H			9003-Fine clayey soils,	3 to 7 percent slope,	moderate erosion
03/C2M			9003-Medium loamy soils,	7 to 12 percent slope,	moderate erosion
03/C2N	11.6	2	9003-Moderate fine loamy soils,	7 to 12 percent slope,	moderate erosion
03/C3N	4.6	1	9003-Moderately fine loamy soils,	7 to 12 percent slope,	moderate erosion
03/C4N	13.0	3	9003-Moderately fine loamy soils,	7 to 12 percent slope,	severe erosion
03/D3N	60.0	14	9003-Moderately fine loamy soils,	12 to 20 percent slope,	moderate erosion
03/D4N			9003-Moderately fine loamy soils,	12 to 20 percent slope,	severe erosion
03/E3N	21.4	5	9003-Moderately fine loamy soils,	20 to 35 percent slope,	moderate erosion
03/E4N	25.8	6	9003-Moderately fine loamy soils,	20 to 35 percent slope,	severe erosion
03/F3N	23.4	5	9003-Moderately fine loamy soils,	35 to 75 percent slope,	moderate erosion
03/F4N	91.0	21	9003-Moderately fine loamy soils,	35 to 75 percent slope,	severe erosion
03S/B3M			9003S-Stony medium loamy soils,	3 to 7 percent slope,	moderate erosion
03S/B4M			9003S-Stony medium loamy soils,	3 to 7 percent slope,	severe erosion
03S/C2M			9003S-Stony medium loamy soils,	7 to 12 percent slope,	slight erosion
04/A1M	38.6	9	9004-Medium loamy soils,	0 to 3 percent slope,	stable erosion
04/B2M	10.2	2	9004-Medium loamy soils,	3 to 7 percent slope,	slight erosion
04/C2M	29.2	7	9004-Medium loamy soils,	7 to 12 percent slope,	slight erosion
05/A1M			9005-Medium loamy soils,	0 to 3 percent slope,	stable erosion
05/A2M			9005-Medium loamy soils,	0 to 3 percent slope,	slight erosion
05/C3M			9005-Medium loamy soils,	7 to 12 percent slope,	moderate erosion
06/A2M	16.1	4	9006-Medium loamy soils,	0 to 3 percent slope,	slight erosion
06/B2M			9006-Medium loamy soils,	0 to 3 percent slope,	slight erosion
07/A2N	4.2	1	9007-Moderately fine loamy soils,	0 to 3 percent slope,	slight erosion
07/B2N			9007-Moderately fine loamy soils,	3 to 7 percent slope,	slight erosion
08/A1M			9008-Medium loamy soils,	0 to 3 percent slope,	stable erosion
08/B1M			9008-Medium loamy soils,	3 to 7 percent slope,	stable erosion
08/E3N			9008-Moderately fine loamy soils,	20 to 35 percent slope,	moderate erosion
09/A1M			9009-Medium loamy soils,	0 to 3 percent slope,	stable erosion
09/B2M			9009-Medium loamy soils,	3 to 7 percent slope,	slight erosion
010/B2N	10.8	2	90010-Moderately fine loamy soils,	3 to 7 percent slope,	slight erosion
010/C4N	7.6	2	90010-Moderately fine loamy soils,	7 to 12 percent slope,	severe erosion



EXPLANATION

SOIL PROFILE NOTES
PROFILE REPRESENTS 5' DEPTH



2.8 --- 2.8 EC mmhos/cm
24 --- 24 Settling Volume (pH 1:5 Soil-Water Suspension)
------ 65 Hydraulic Conductivity in/hr (Disturbed Samples)
------ 8.4 pH 1:5 Soil-Water Suspension
8.1 pH Soil-CaCl₂ Suspension

SOIL PROFILE SYMBOLS

Cb	Cobble
Gr	Gravel
S	Sand
LS	Loamy Sand
SL	Sandy Loam
L	Loam
SiL	Silt Loam
SCL	Sandy Clay Loam
CL	Clay Loam
SiCL	Silty Clay Loam
SC	Sandy Clay
C	Clay
SiC	Silty Clay
Sh	Shale
Ss	Sandstone
F	Fine
Li	Light
M	Medium
Hv	Heavy

$$\text{Slope} \rightarrow \frac{03}{D\,3\,N}$$

Series: 03
Slope: D
Textural group: N
Erosion class: 3

Series Name 9001 through 90011

SLOPE CLASS	EROSION CLASS
A -- 0 - 3 Percent	1 ---- Stable
B -- 3 - 7 Percent	2 ---- Slight
C -- 7 - 12 Percent	3 -- Moderate
D -- 12 - 20 Percent	4 ---- Severe
E -- 20 - 35 Percent	5 --- Critical
F -- 35 - 75 Percent	

TEXTURAL GROUP

V { Sand, Loamy Sand } Coarse } Sandy
I { Sandy Loam, Fine Sandy Loam } Moderately Coarse } Loamy
M { Very Fine Sandy Loam, Loam, Silt Loam } Medium } Loamy
N { Sandy Clay Loam, Clay Loam, Silty Clay Loam } Moderately Fine } Loamy
H { Sandy Clay, Silty Clay, Li, M & H Clay } Fine } Clayey

INFORMATIVE SYMBOLS

B - Baked rock exposed
R - Massive surface rock
o - Saline
b - Shale exposed
- Grease wood
⊗ - Check hole

N

SEC. 2, T4S., R45E.
POWDER RIVER CO.

400 0 400 800 1200
SCALE OF FEET

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

DETAILED SOIL INVENTORY

OTTER CREEK STUDY SITE
OTTER CREEK COAL FIELD

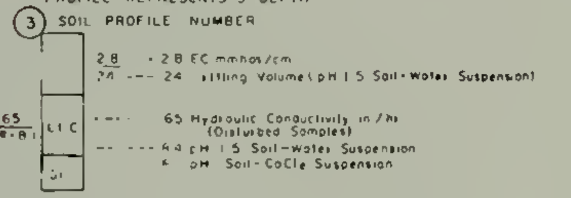
DESIGNED H. B. WARD SUBMITTED H B Ward
DRAWN E. G. H. RECOMMENDED
CHECKED H. B. W. APPROVED C.Q. Gibbs

GREAT FALLS, MONTANA FEBRUARY 1978 1305-600-25

	LOCATION											
	T. 3 S., R. 45 E.						T. 4 S., R. 45 E.					
	Sec. 26		Sec. 34		Sec. 35		Sec. 2		Sec. 3			
Symbol	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Total	Name
01/A1M							35.9	9			35.9	9001-Medium loamy soils, 0 - 3% slope, stable erosion
02/A1N	5.6	2	9.2	2	1.0	-					15.8	9002-Moderately fine loamy soils, 0 - 3% slope, stable erosion
02/B2N							5.2	1			5.2	9002-Moderately fine loamy soils, 3 - 7% slope, slight erosion
02/C2N	5.2	1	22.2	5							27.4	9002-Moderately fine loamy soils, 7 - 12% slope, slight erosion
02/C3N							18.1	4	7.0	2	25.1	9002-Moderately fine loamy soils, 7 - 12% slope, moderate erosion
03/B2N	12.0	3	35.9	8	17.4	3	9.3	2	17.5	5	92.1	9003-Moderately fine loamy soils, 3 - 7% slope, slight erosion
03/B3H	13.3	4			32.0	5					45.3	9003-Fine clayey soils, 3 - 7% slope, moderate erosion
03/C2M			35.6	8							35.6	9003-Medium loamy soils, 7 - 12% slope, moderate erosion
03/C2N			8.8	2	18.0	3	11.6	2	5.1	1	43.5	9003-Moderate fine loamy soils, 7 - 12% slope, moderate erosion
03/C3N	4.8	1	76.1	18	11.5	2	4.6	1			97.0	9003-Moderately fine loamy soils, 7 - 12% slope, moderate erosion
03/C4N	7.4	2					13.0	3			20.4	9003-Moderately fine loamy soils, 7 - 12% slope, severe erosion
03/D3N	15.8	4	27.5	6	18.1	3	60.0	14	36.4	11	157.8	9003-Moderately fine loamy soils, 12 - 20% slope, moderate erosion
03/D4N	2.2	1	28.5	7							30.7	9003-Moderately fine loamy soils, 12 - 20% slope, severe erosion
03/E3N	17.1	5	7.9	2	19.2	3	21.4	5	50.8	15	116.4	9003-Moderately fine loamy soils, 20 - 35% slope, moderate erosion
03/E4N	19.9	6	33.7	8	35.9	6	23.8	6	56.4	17	171.7	9003-Moderately fine loamy soils, 20 - 35% slope, severe erosion
03/F3N			12.2	3	32.2	5	23.4	5	65.2	19	133.0	9003-Moderately fine loamy soils, 35 - 75% slope, moderate erosion
03/F4N	37.4	10	47.3	11	156.5	24	91.0	21	24.2	7	356.0	9003-Moderately fine loamy soils, 35 - 75% slope, severe erosion
03S/B3M	20.7	6			0.5						21.2	9003S-Stony medium loamy soils, 3 - 7% slope, moderate erosion
03S/B4M	5.2	1									5.2	9003S-Stony medium loamy soils, 3 - 7% slope, severe erosion
03S/C2M	21.1	6	3.8	1							24.9	9003S-Stony medium loamy soils, 7 - 12% slope, slight erosion
04/A1M	0.7				0.2	-	38.6	9			39.5	9004-Medium loamy soils, 0 - 3% slope, stable erosion
04/B2M	11.0	3	5.6	1	73.2	11	10.2	2	38.2	11	138.2	9004-Medium loamy soils, 3 - 7% slope, slight erosion
04/C2M	2.7	1	8.2	2	1.6	-	29.2	7			39.0	9004-Medium loamy soils, 7 - 12% slope, slight erosion
05/A1M	5.0	1	30.7	7	68.0	11					103.7	9005-Medium loamy soils, 0 - 3% slope, stable erosion
05/A2M	30.3	8									30.3	9005-Medium loamy soils, 0 - 3% slope, slight erosion
05/C3M	22.5	7									22.5	9005-Medium loamy soils, 7 - 12% slope, moderate erosion
06/A2M	2.6	1	7.2	2	0.3	-	16.1	4	.3		26.5	9006-Medium loamy soils, 0 - 3% slope, slight erosion
06/B2M	9.4	3	7.3	2	0.2	-					19.1	9006-Medium loamy soils, 0 - 3% slope, slight erosion
07/A2N	36.9	10	1.5		6.0	1	4.2	1	17.0	5	65.6	9007-Moderately fine loamy soils, 0 - 3% slope, slight erosion
07/B2N	10.0	4			151.7	23					161.7	9007-Moderately fine loamy soils, 3 - 7% slope, slight erosion
08/A1M	3.9	1	14.9	3							18.8	9008-Medium loamy soils, 0 - 3% slope, stable erosion
08/B1M	1.0		8.4	2					3.6	1	13.0	9008-Medium loamy soils, 3 - 7% slope, stable erosion
08/E3N									19.5	6	19.5	9008-Moderately fine loamy soils, 20 - 35% slope, moderate erosion
09/A1M	13.7	4									11.5	9009-Medium loamy soils, 0 - 3% slope, stable erosion
09/B2M	17.6	5			0.1						17.7	9009-Medium loamy soils, 3 - 7% slope, slight erosion
010/B2N							10.8	2			10.8	90010-Moderately fine loamy soils, 3 - 7% slope, slight erosion
010/C4N							7.6	2			7.6	90010-Moderately fine loamy soils, 7 - 12% slope, severe erosion

EXPLANATION

SOIL PROFILE NOTES
PROFILE REPRESENTS 5' DEPTH



③ SOIL PROFILE NUMBER

2.8 - 2.8 EC mmhos/cm
24 --- 24 Wilting Volume (pH 1 5 Soil-Water Suspension)
65 Hydraulic Conductivity in/hr (Disturbed Samples)
6.4 pH 1 5 Soil-Water Suspension
pH Soil-CaCl₂ Suspension

SOIL PROFILE SYMBOLS

Cb	Cobble
Gr	Gravel
S	Sand
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L	Loam
SiL	Silt Loam
SCL	Sandy Clay Loam
CL	Clay Loam
SiCL	Silty Clay Loam
SC	Sandy Clay
C	Clay
SiC	Silty Clay
Sh	Shale
Ss	Sandstone
F	Fine
Lt	Light
M	Medium
Hv	Heavy

$$\frac{03}{D\,3\,N}$$

Series — 03
Slope — D
3 — Erosion class
N — Textural group

Series Name 9001 through 90010

SLOPE CLASS	EROSION CLASS
A -- 0 - 3 Percent	1 ---- Stable
B -- 3 - 7 Percent	2 ---- Slight
C -- 7 - 12 Percent	3 -- Moderate
D -- 12 - 20 Percent	4 ---- Severe
E -- 20 - 35 Percent	5 --- Critical
F -- 35 - 75 Percent	

TEXTURAL GROUP

V { Sand, Loamy Sand } Coarse } Sandy
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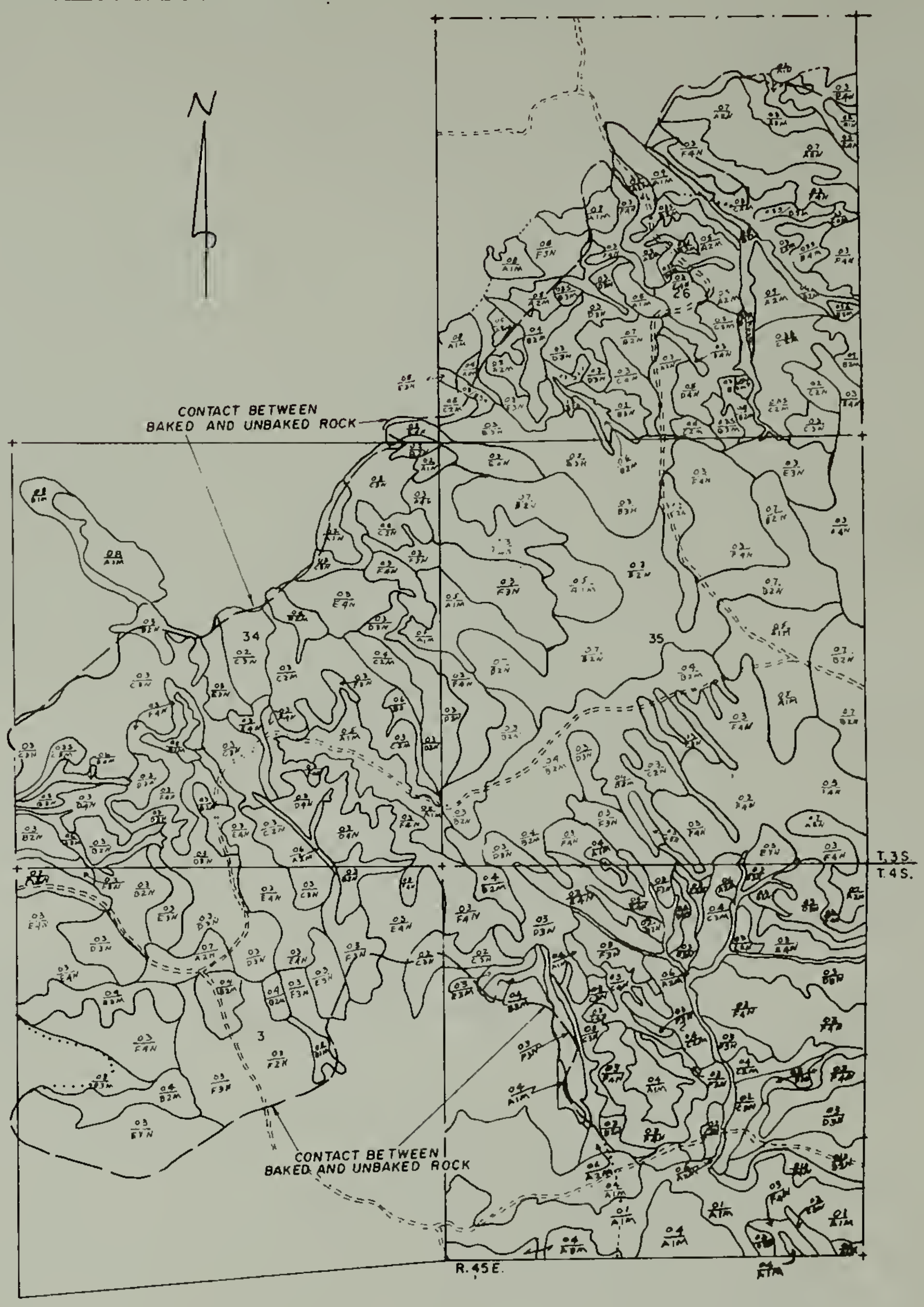
M { Very Fine Sandy Loam, Loam, Silt Loam } Medium } Loamy
N { Sandy Clay Loam, Clay Loam, Silty Clay Loam } Moderately Fine } Loamy
H { Sandy Clay, Silty Clay, Lt, M & H Clay } Fine } Clayey

INFORMATIVE SYMBOLS

B - Baked rock exposed
R - Massive surface rock
o - Saline
b - Shale exposed
- Grease wood
⊗ - Check hole


N
CONTACT BETWEEN BAKED AND UNBAKED ROCK
CONTACT BETWEEN BAKED AND UNBAKED ROCK
26
34
35
3
T.3S.
T.4S.
R.45E.

SCALE 1" = 1000'

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

SOIL INVENTORY

OTTER CREEK STUDY SITE
OTTER CREEK COAL FIELD

DRAWN H. B. WARD SUBMITTED H. B. Ward
TRACED E. G. H. RECOMMENDED
CHECKED H. B. W. APPROVED
GREAT FALLS, MONTANA FEBRUARY 1975 1305-600-26

VEGETATION, SOIL-MOISTURE-RETENTION CHARACTERISTICS AND SOIL ERODIBILITY

Reclamation of surface-mined lands will be more successful and be accomplished in less time if surface soils are stock-piled and then replaced on the reshaped disturbed overburden. Effective use of the surface soils requires a knowledge of their moisture retention characteristic or the relationship between the quantity of moisture in the soil and the forces involved in retaining that moisture.

The moisture retention characteristic for a soil can be defined if two physical properties are known: (1) a measure of the surface available within a soil for adsorption of moisture as films, and (2) a measure of the porosity of the soil that exists at the time for which the characteristic is to be defined.

Moisture contents may be defined on a weight basis (grams of water per gram of soil) or on a volume basis (cubic centimetres of water per cubic centimetre of soil). Conversions from weight to volume are made by multiplication by the dry bulk density of the soil.

The forces of moisture retention are defined in numerous ways: atmospheres, bars, feet of water, pounds per square inch, ergs per gram, etc. This report will use pF, (Schofield, 1935) which is defined as the common logarithm of the height in centimetres of a column of water that requires an equivalent force to support it. The use of pF simplifies computations and permits visualization of the forces as physical dimensions.

For equilibrium conditions a pF of 1 represents the retention force at a height of 10 centimetres above a water table. At 100 centimetres above a water table the stress would be pF 2 and at 1,000 centimetres (10 metres or 30.48 feet) the equilibrium stress would be pF 3.0.

McQueen and Miller (1974) described a model for synthesizing the soil moisture characteristic from limited data. The curve is divided into segments and a separate mechanism of moisture retention determines each segment (see figure 6). For the range of retention forces from pF 2.5 to 5.0 (3 to 1,000 metres) moisture is retained as films on particle surfaces by molecular adsorptive forces that vary inversely with a power of the film thickness. This segment of the characteristic is a straight line intersecting the zero moisture content axis at pF 6.25 and passing through any valid pF versus moisture content data points that are known.

For retention forces greater than pF 5.0 the moisture is adsorbed to surfaces in a pseudo-molecular structure and the moisture characteristic is cyclic. However, it can be approximated by a straight line between the zero moisture content axis at pF 7.0 and the adsorbed segment at pF 5.0.

For moisture retention forces less than pF 2.9 surface tension forces may add additional moisture in the form of capillary water bodies to

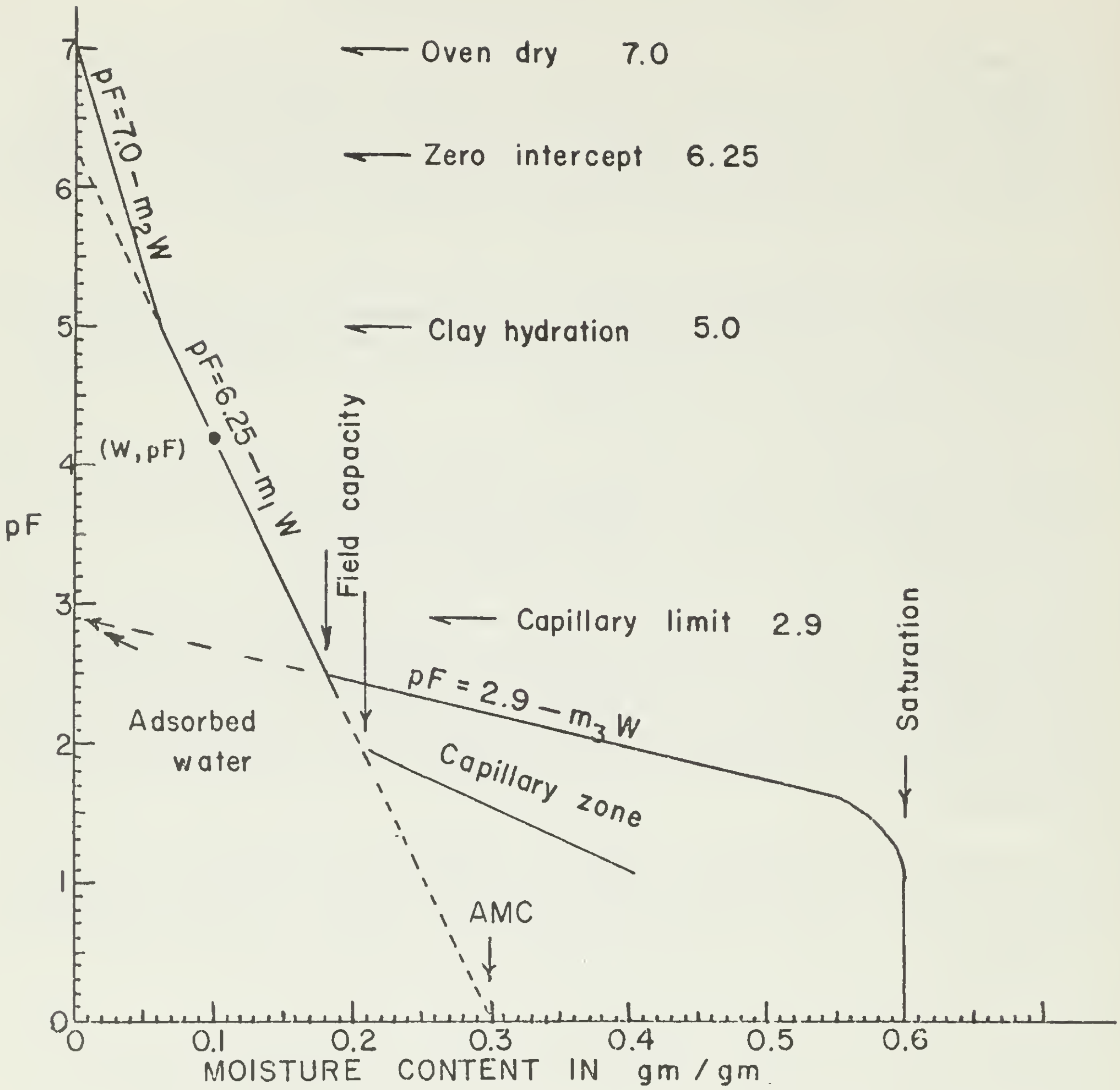


Figure 6.--Definition diagram for method of synthesizing soil moisture characteristic from limited data (after McQueen and Miller, 1974). In this example the permanent wilting percentage was reported as 10 and saturation percentage as 60.

the moisture retained as adsorbed films. This capillary segment of the soil moisture characteristic is unstable, because of alterations in pore geometry and the effects of a hysteresis loop so it can only be defined in terms of limits or ranges. However the probably configuration can be predicted for given sets of conditions.

Synthesis of a typical soil moisture characteristic is illustrated in figure 6. The adsorbed water segment is defined from one or more data points. In this report all retention data were obtained with the wide range method of McQueen and Miller (1968) but any valid data could be used. The intercept of the adsorbed water segment at pF 6.25 has been established statistically from a large mass of data and should be considered valid for most soils. Structured water (the segment above pF 5.0) can usually be removed from a soil profile only by evaporation near the soil surface so it need not be considered when computing transpiration. The adsorbed moisture segment is extended to the zero pF axis to indicate the computation for AMC (the maximum adsorbed moisture at a stress of pF zero).

Procedure and Data Presentation

Soil profiles were sampled at locations indicated on the vegetation map (plate 38). A sample was obtained for each 10 cm depth increment in each profile using a 2-inch diameter barrel type soil auger. Samples were examined in the field to define tentative horizon depths and then sealed in plastic bags and cans for transportation to the laboratory. A moisture stress sensor (filter paper) was included in each sample.

Vegetation at each sampling site was identified, measured and photographed to define plant community associations. The results of the vegetation measurements are presented on table 15. The soil moisture characteristics and photographs of the 12 sites sampled are shown on plate 39.

Data resulting from the soil analyses are presented in table 16. Definitions and methods for the items reported are as follows:

H=Soil Horizon determined during field examination but adjusted where bulk density, electrical conductivity, pH or root data indicated a change should be made.

1=That portion of the soil profile that is wetted by capillary or gravity flow during recharge events. The A Horizon or leached zone.

2=That portion of the soil profile that receives moisture after recharge events by displacement of the moisture in the 1(A) Horizon. Moisture movement is usually in the form of film flow. A zone of accumulation of clay and salt. Usually corresponds to the B horizon

3=That portion of the soil profile that receives moisture in the vapor phase. A zone of minimal moisture change. May coincide with the B_2 horizon.

Table 15-Percent aerial cover of vegetation and percent cover of mulch, bare and rock for vegetation types on the Otter Creek Coal Field Study Site

	Habitat..............	Pine savannah		Grassland and shrubland						Breaks			Flood-plain
	Sample site number....	2	12	1	6	8	9	10	11	3	4	5	7
Species													
Trees													
Pinus ponderosa	Ponderosa pine	2.0	30.0	--	--	--	--	--	--	--	--	--	--
Shrubs													
Artemisia cana	Silver sagebrush	--	--	--	--	--	--	--	--	--	--	--	16.0
Artemisia dracunculus	Falsetarragon	--	--	4.2	--	--	--	--	--	--	--	--	--
Artemisia frigida	Fringed sagebrush	--	0.2	--	--	--	--	--	0.8	1.0	--	--	--
Artemisia tridentata	Big sagebrush	--	--	--	--	23.8	2.8	8.5	--	--	13.2	--	--
Chrysothamnus nauseosus	Rubber rabbitbrush	--	--	--	--	--	--	--	--	--	--	0.2	--
Eriogonum multiceps	Wild buckwheat	--	--	--	--	--	--	--	--	11.8	--	1.0	--
Gutierrezia sarothrae	Snakeweed	1.9	0.7	--	--	--	--	--	0.2	1.8	0.2	1.5	--
Opuntia polyacantha	Plains pricklypear	--	--	--	--	0.2	--	1.5	--	--	--	--	--
Sarcobatus vermiculatus	Greasewood	--	--	--	--	--	--	--	--	--	--	14.5	--
Grasses													
Agropyron smithii	Western wheatgrass	--	0.8	2.5	20.8	3.8	--	3.5	20.2	4.0	6.3	6.0	24.2
Agropyron spicatum	Bluebunch wheatgrass	4.0	17.2	--	--	10.5	--	--	--	2.8	3.5	--	--
Andropogon scoparius	Little bluestem	54.5	4.0	--	--	--	1.0	--	--	--	--	--	--
Aristida longiseta	Red threeawn	--	--	--	1.8	2.7	--	--	--	--	--	--	--
Bouteloua curtipendula	Side-oats grama	--	2.0	--	--	--	--	--	--	--	--	--	--
Bouteloua gracilis	Blue grama	1.3	--	3.8	11.8	7.8	--	20.1	29.5	--	0.8	--	4.8
Bromus commutatus	Hairy chess	--	--	2.0	13.5	6.7	0.5	3.0	2.0	0.8	0.2	--	11.2
Calamovilfa longifolia	Prairie sandreed	1.3	1.5	--	--	--	84.2	--	--	--	--	--	--
Distichlis stricta	Saltgrass	--	--	--	--	--	--	1.1	--	--	--	0.5	--
Festuca octoflora	Six-weeks fescue	--	--	1.8	--	--	--	0.7	--	--	--	--	--
Koeleria cristata	Junegrass	2.0	--	2.2	--	0.7	1.0	0.7	--	--	5.9	--	--
Muhlenbergia cuspidata	Stonyhills muhly	--	0.8	--	--	--	--	--	--	--	--	--	--
Poa secunda	Sandberg's bluegrass	--	--	--	0.8	0.2	--	2.0	--	--	0.5	--	--
Schedonnardus paniculatus	Tumblegrass	--	--	--	--	--	--	--	2.7	--	--	--	--
Sporobolus cryptandrus	Sand dropseed	--	1.0	--	1.0	--	--	0.7	--	--	--	--	--
Stipa comata	Needle-and-thread	2.6	1.0	54.5	0.2	9.0	1.2	1.7	--	--	7.8	--	11.3
Stipa viridula	Green needlegrass	--	--	--	--	0.8	--	--	--	--	23.0	--	--
Forbs													
Grindelia squarrosa	Gumweed	--	--	--	1.1	--	--	--	--	--	--	--	--
Lepidium densiflora	Pepperweed	--	--	--	--	--	--	--	--	--	--	--	0.2
Linum sp.	Flax	--	--	--	--	--	--	1.0	--	--	--	--	0.5
Phlox hoodii	Hoods phlox	--	--	--	--	--	--	--	--	--	--	--	--
Phlox longifolia	Longleaf phlox	--	--	--	--	--	--	--	--	--	0.2	--	--
Plantago purshii	Indianwheat	--	--	0.2	0.7	--	--	0.5	--	--	--	--	--
Psoralea argophylla	Silverleaf psoralea	--	--	0.3	--	--	0.5	--	--	--	0.2	--	--
Polygala alba	Polygala	2.5	--	--	--	--	--	--	--	--	--	--	--
Ratibida columnifera	Prairie coneflower	--	--	--	0.5	--	--	0.5	--	--	--	--	--
Sphaeralcea coccinea	Salmon-colored mallow	--	--	0.8	2.0	--	--	--	--	--	0.5	--	--
Tragopogon pratense	Oyster salsify	--	--	0.5	1.8	2.5	--	--	--	--	0.5	--	1.0
Sedge													
Carex filifolia	Threadleaf sedge	3.0	0.5	--	--	--	--	--	--	--	--	--	--
Mulch		19.9	30.5	26.0	42.0	29.8	8.8	29.0	24.8	5.8	24.0	4.7	30.8
Moss		--	--	0.2	--	--	--	--	--	--	--	--	--
Rock		2.5	8.8	--	--	--	--	--	--	5.8	2.2	6.5	--
Bare		2.5	1.0	1.0	2.0	1.5	--	25.5	19.8	66.2	11.0	65.1	--

Table 16 Hydrologic data for soils on the Otter Creek study site near Ashland Montana.

MONT SITE 1 DATE: 8/10/74 SAMPLE NO. 1 VEGETATION TYPE: Needle and thread-Falseterragon-Blue grama

M DPTH	SM	VOL WT	VOL AVE	FVR	VMC	SMC	TVR	G/CC	SVR	PF	AMC	CMC	LS	EC	PH	ROOTS	ET	TRAN	EK	IR
10	0.0938	1.07	0.0	1.482	.559	.354	0.938	1.59	1.257	3.49	.213	0.141	.027	0.368	7.38	0.0	172.	.594	0.447	0.259
20	0.0779	1.21	1.14	1.328	.501	.306	0.810	1.67	1.072	4.38	.261	0.045	.040	0.448	7.38	0.0	55.	.833	0.575	0.847
30	0.0815	1.36	1.21	1.184	.447	.358	0.948	1.65	1.181	4.15	.242	0.115	.040	0.424	7.40	0.0	26.	.555	0.707	1.994
1 AVE	0.0844	1.21		1.331		.339		1.64		4.01	.239		.036	0.413	7.39			.794	0.576	1.043
40	0.0903	1.86	1.48	0.795	.300	.341	1.009	1.63	1.245	4.06	.258	0.123	.027	0.402	7.39	0.0	12.	.578	0.927	4.454
50	0.0952	1.11	1.44	0.836	.315	.352	0.932	1.67	1.145	4.04	.269	0.083	.0	0.210	7.53	0.0	8.	.538	1.107	5.453
60	0.0894	1.23	1.40	0.893	.337	.283	0.749	1.71	0.988	3.97	.246	0.037	.0	0.176	7.62	0.0	8.	.419	1.107	5.607
70	0.0879	1.29	1.21	1.189	.449	.303	0.802	1.71	1.019	4.04	.249	0.054	.0	0.187	7.70	0.0	8.	.481	1.107	5.917
80	0.0853	1.28	1.27	1.091	.412	.296	0.785	1.69	1.033	4.00	.237	0.060	.007	0.197	7.53	0.0	9.	.443	1.049	5.115
90	0.0824	1.51	1.36	0.949	.359	.272	0.722	1.73	0.949	4.44	.285	-.013	.0	0.195	7.50	0.0	9.	.378	1.049	4.912
2 AVE	0.0884	1.38		0.959		.314		1.69		4.09	.257		.006	0.228	7.59			.479	1.057	5.413
100	0.0823	2.79	1.86	0.426	.161	.274	0.727	1.79	0.887	4.07	.236	0.038	.0	0.234	7.60	0.0	5.	.280	1.431	9.139
110	0.0930	2.54	2.28	0.163	.061	.256	0.677	1.81	0.838	3.99	.258	-.002	.0	0.278	7.57	0.0	7.	.278	1.183	6.260
3 AVE	0.0876	2.66		0.294		.265		1.80		4.03	.247		.0	0.256	7.58			.279	1.307	7.699
PROFILE AVE	0.0872	1.57		0.940		.312		1.70		4.06	.250		.013	0.283	7.54			.529	0.972	4.637

MONT SITE 2 DATE: 8/10/74 SAMPLE NO. 1 VEGETATION TYPE: Ponderosa pine-Little bluestem

M DPTH	SM	VOL WT	VOL AVE	FVR	VMC	SMC	TVR	G/CC	SVR	PF	AMC	CMC	LS	EC	PH	ROOTS	ET	TRAN	EK	IR
10	0.0921	0.94	0.0	1.809	.583	.407	1.078	1.60	1.330	3.59	.216	0.191	.013	0.397	7.40	0.0	1440.	.895	0.317	0.039
20	0.0733	1.15	1.05	1.530	.577	.405	1.074	1.60	1.328	4.31	.236	0.169	.040	0.326	7.52	0.0	767.	.845	0.347	0.072
30	0.0620	1.32	1.14	1.327	.501	.378	1.001	1.66	1.200	4.36	.205	0.173	.027	0.255	7.56	0.0	43.	.918	0.512	1.263
1 AVE	0.0758	1.14		1.555		.397		1.62		4.08	.219		.027	0.326	7.49			.886	0.425	0.459
40	0.0426	1.47	1.31	1.016	.384	.336	0.890	1.73	1.047	4.30	.137	0.199	.013	0.223	7.55	0.0	46.	.960	0.501	1.129
50	0.0467	2.44	1.74	0.520	.196	.294	0.778	1.83	0.873	4.32	.152	0.142	.027	0.212	7.50	0.0	77.	.942	0.530	0.542
60	0.0717	1.23	1.71	0.546	.206	.363	0.961	1.72	1.100	3.67	.174	0.189	.020	0.219	7.47	0.0	77.	.958	0.530	0.709
70	0.0990	2.14	1.94	0.367	.139	.326	0.853	1.69	1.079	3.19	.202	0.124	.013	0.246	7.47	0.0	75.	.929	0.533	0.559
80	0.1252	1.73	1.70	0.557	.210	.295	0.781	1.77	0.938	2.45	.206	0.089	.007	0.272	7.53	0.0	530.	.974	0.357	0.091
90	0.1284	1.77	1.88	0.408	.154	.320	0.849	1.77	0.977	2.36	.207	0.113	.007	0.321	7.46	0.0	372.	.986	0.389	0.134
2 AVE	0.0855	1.80		0.569		.322		1.75		3.36	.180		.014	0.249	7.50			.966	0.492	0.561
100	0.1316	1.67	1.72	0.537	.203	.316	0.837	1.72	1.028	2.56	.223	0.093	.020	0.417	7.40	0.0	429.	.985	0.380	0.115
110	0.1072	2.09	1.85	0.435	.164	.314	0.833	1.80	0.935	2.45	.176	0.138	.020	0.676	7.25	0.0	297.	.965	0.404	0.173
120	0.0916	2.23	2.00	0.327	.123	.297	0.787	1.77	0.942	2.80	.166	0.131	.013	1.244	7.20	0.0	67.	.911	0.549	0.720
130	0.1546	1.70	2.01	0.320	.121	.354	0.939	1.72	1.087	2.74	.275	0.079	.020	1.938	7.08	0.0	8..	.777	0.515	0.619
3 AVE	0.1212	1.92		0.405		.320		1.75		2.64	.210		.018	1.069	7.23			.909	0.462	0.405
PROFILE	0.0943	1.68		0.746		.339		1.72		3.32	.198		.018	0.519	7.41			.930	0.467	0.490

Table 16 (Cont.)

MONT SITE 3 DATE: 8/10/74 SAMPLE NO. 1 VEGETATION TYPE: Wild buckwheat

M DPTH	SM	VOL WT	VOL AVE	FVR	VMC	SMC	TVR	G/CC	SVR	PF	AMC	CMC	LS	EC	PH	ROOTS	ET	TRAN	EK	IR
10	0.0541	0.85	0.0	2.125	.802	.338	0.896	1.69	1.099	4.60	.206	0.132	.020	0.833	7.26	0.0	43.	.989	0.612	1.171
1 AVE	0.0541	0.85		2.125		.338		1.69		4.60	.206		.020	0.833	7.26			.989	0.612	1.171
20	0.0413	1.85	1.35	0.964	.364	.368	0.975	1.72	1.108	4.82	.181	0.187	.020	0.929	7.23	0.0	68.	.909	0.545	0.912
30	0.0567	1.73	1.48	0.795	.300	.351	0.930	1.73	1.069	4.37	.189	0.162	.033	1.029	7.22	0.0	70.	.949	0.542	0.766
40	0.0671	1.93	1.84	0.442	.167	.373	0.989	1.70	1.140	4.27	.212	0.161	.040	1.534	7.11	0.0	65.	.893	0.519	0.648
2 AVE	0.0551	1.84		0.734		.364		1.72		4.49	.194		.031	1.164	7.19			.917	0.535	0.742
50	0.0613	1.91	1.86	0.426	.161	.344	0.912	1.73	1.059	4.27	.193	0.151	.033	2.049	7.00	0.0	94.	.984	0.507	0.552
50	0.0613	2.42	2.09	0.271	.102	.336	0.891	1.73	1.047	4.36	.203	0.133	.027	1.984	7.02	0.0	833.	.789	0.342	0.052
3 AVE	0.0613	2.16		0.349		.340		1.73		4.31	.198		.030	2.017	7.01			.936	0.425	0.312
70	0.3033	0.81	1.71	0.550	.208	.575	1.523	1.21	2.449	4.34	.996	-.422	****	1.042	7.10	0.0	7.	.406	1.183	7.525
80	0.5206	0.75	1.32	1.000	.377	.700	1.856	1.12	3.023	3.94	****	-.708	****	1.126	7.02	0.0	2.	.097	3.322	27.535
4 AVE	0.4120	0.78		0.775		.638		1.16		4.14	****		****	1.084	7.06			.252	2.253	17.530
1,2 63 PROFILE	.0570	1.78		0.838		.352		1.72		4.45	.197		.029	1.393	7.14			.885	.511	.670

MONT SITE 4 DATE: 8/10/74 SAMPLE NO. 1 VEGETATION TYPE: Big sagebrush-Green needlegrass

M DPTH	SM	VOL WT	VOL AVE	FVR	VMC	SMC	TVR	G/CC	SVR	PF	AMC	CMC	LS	EC	PH	ROOTS	ET	TRAN	EK	IR
10	0.0537	1.05	0.0	1.531	.578	.365	1.022	1.59	1.309	5.34	.391	-.006	.053	0.532	7.33	15.00	343.	.859	0.394	0.154
20	0.0534	1.38	1.21	1.186	.448	.344	0.911	1.65	1.158	4.96	.255	0.088	.040	0.493	7.30	10.00	113.	.705	0.487	0.445
30	0.0698	1.87	1.43	0.851	.321	.429	1.138	1.60	1.367	4.71	.279	0.150	.033	0.463	7.40	9.00	41.	.583	0.620	1.395
1 AVE	0.0595	1.43		1.190		.386		1.61		5.01	.309		.042	0.496	7.34			.716	0.501	0.565
40	0.0659	1.44	1.56	0.697	.263	.353	0.934	1.68	1.133	4.69	.265	0.088	.053	0.424	7.30	9.00	195.	.594	0.437	0.269
50	0.0679	1.42	1.57	0.683	.258	.365	0.958	1.70	1.128	4.58	.254	0.111	.057	0.407	7.30	6.00	126.	.590	0.475	0.431
50	0.0670	2.25	1.70	0.557	.210	.379	1.005	1.66	1.202	4.82	.293	0.086	.040	0.552	7.28	4.00	330.	.505	0.397	0.164
70	0.0527	1.27	1.65	0.608	.230	.373	0.987	1.67	1.178	4.63	.204	0.169	.027	0.696	7.25	3.00	90.	.771	0.512	0.501
2 AVE	0.0634	1.59		0.636		.367		1.63		4.68	.254		.047	0.520	7.28			.590	0.455	0.355
80	0.0525	1.53	1.69	0.572	.216	.330	0.874	1.70	1.073	4.35	.173	0.157	.013	1.190	7.10	4.00	13.	.894	0.599	3.871
90	0.0524	1.79	1.53	0.730	.276	.290	0.769	1.77	0.932	4.16	.157	0.134	.013	0.850	7.20	1.00	10.	.968	1.000	4.754
100	0.0532	1.57	1.63	0.626	.235	.296	0.785	1.75	0.963	4.04	.151	0.146	.007	0.929	7.11	1.00	11.	.974	0.960	4.342
110	0.0725	2.60	1.99	0.335	.126	.116	0.307	1.77	0.671	4.06	.207	-.091	.040	2.033	7.10	2.00	15.	.992	0.850	1.460
120	0.0669	1.27	1.81	0.462	.174	.326	0.853	1.69	1.079	3.94	.181	0.145	.020	1.799	7.00	1.00	10.	.959	1.000	4.951
130	0.0745	2.04	1.97	0.345	.130	.356	0.944	1.69	1.125	4.06	.213	0.143	.020	1.269	7.10	0.0	13.	.935	0.598	4.065
140	0.0850	1.43	1.58	0.676	.255	.360	1.008	1.69	1.164	4.09	.246	0.134	.040	2.381	6.98	0.0	19.	.910	0.792	2.925
150	0.0610	1.95	1.81	0.466	.176	.331	0.877	1.75	1.015	4.09	.177	0.154	.007	1.330	7.09	0.0	14.	.899	0.873	3.709
150	0.0819	1.52	1.63	0.622	.235	.368	0.975	1.72	1.107	4.16	.245	0.122	.033	2.232	6.96	0.0	11.	.919	0.960	5.020
3 AVE	0.0666	1.74		0.537		.310		1.73		4.11	.194		.021	1.557	7.07			.907	0.913	3.900
PROFILE	0.0643	1.65		0.684		.339		1.69		4.42	.231		.032	1.099	7.17			.917	0.721	2.410

Table 16 (Cont.)

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MONT  SITE   5  DATE: 8/10/74  SAMPLE NO. 1  VEGETATION TYPE: Greasewood
               VOL   VOL
H DPTH   SM    WT    AVE  FVR   VMC  SMC  TVR   G/CC SVR   PF   AMC  CMC   LS    EC    PH  ROOTS   ET  TRAN  EK     IR

  10 0.0710 1.25 0.0  1.119 .422 .625 1.657 1.55 1.779 5.35 .493 0.132 .140  5.410  6.85  6.00  220. .957 0.427  0.324
  20 0.0810 1.61 1.43 0.854 .322 .491 1.302 1.62 1.439 4.83 .357 0.134 .107  3.846  6.42 10.00  176. .923 0.445  0.352
  30 0.0878 1.39 1.42 0.869 .328 .444 1.176 1.72 1.224 4.23 .272 0.172 .100  4.167  6.86  4.00  293. .915 0.405  0.215

1AVE  0.0799 1.42      0.947      .520       1.63       4.80 .374       .116  4.808  6.84              .932 0.425  0.300

  40 0.0998 1.25 1.42 0.869 .326 .531 1.406 1.57 1.583 4.23 .309 0.222 .093  4.630  6.80  1.00  435. .953 0.379  0.149
  50 0.1095 1.50 1.38 0.920 .347 .465 1.232 1.65 1.353 4.12 .323 0.142 .080  4.902  6.90  1.00  238. .937 0.421  0.263
  60 0.0961 1.43 1.39 0.905 .341 .431 1.141 1.67 1.270 4.03 .271 0.160 .033  4.808  6.79  1.00  315. .907 0.400  0.190
  70 0.1124 1.65 1.52 0.738 .279 .417 1.106 1.63 1.304 3.99 .311 0.107 .040  5.000  6.59  1.00  172. .821 0.447  0.333

2AVE  0.1045 1.46      0.858      .461       1.63       4.09 .303       .062  4.835  6.77              .919 0.412  0.234

  80 0.1276 1.60 1.56 0.698 .263 .399 1.057 1.69 1.193 3.92 .343 0.056 .040  5.435  6.58  1.00  392. .515 0.356  0.147
  90 0.1153 1.81 1.69 0.571 .215 .442 1.171 1.68 1.274 3.97 .317 0.125 .087  4.902  6.55  1.00  294. .948 0.405  0.209
 100 0.1240 1.78 1.73 0.531 .200 .478 1.267 1.68 1.331 3.88 .327 0.151 .093  5.208  6.92  0.0   376. .970 0.359  0.172
 110 0.1311 1.86 1.82 0.458 .173 .449 1.190 1.70 1.259 3.79 .334 0.115 .050  5.319  6.95  0.0   258. .971 0.415  0.243
 120 0.1392 1.90 1.85 0.434 .164 .463 1.226 1.67 1.321 3.87 .364 0.099 .073  5.435  6.88  0.0   213. .958 0.429  0.245
 130 0.1387 1.79 1.85 0.432 .163 .462 1.223 1.71 1.265 4.04 .393 0.069 .080  5.814  6.97  0.0   163. .934 0.442  0.352
 140 0.1310 1.87 1.85 0.430 .162 .442 1.172 1.72 1.222 3.90 .349 0.093 .067  5.682  6.92  0.0   195. .955 0.437  0.322
 150 0.1342 1.82 1.83 0.452 .170 .443 1.173 1.65 1.317 4.07 .385 0.057 .073  5.952  6.94  0.0   154. .834 0.457  0.392
 160 0.1227 2.35 2.01 0.316 .119 .405 1.075 1.74 1.141 4.06 .351 0.055 .053  5.102  6.95  0.0   280. .910 0.409  0.213

3AVE  0.1293 1.86      0.480      .442       1.69       3.94 .351       .070  5.428  6.89              .888 0.419  0.261
 PROFILE
      0.1138 1.68      0.662      .462       1.67       4.14 .344       .076  5.163  6.85              .904 0.418  0.261

MONT  SITE   6  DATE: 8/10/74  SAMPLE NO. 1  VEGETATION TYPE: Western wheatgrass-Blue grama
               VOL   VOL
H DPTH   SM    WT    AVE  FVR   VMC  SMC  TVR   G/CC SVR   PF   AMC  CMC   LS    EC    PH  ROOTS   ET  TRAN  EK     IR

  10 0.0615 0.99 0.0  1.686 .636 .450 1.192 1.57 1.447 5.14 .347 0.103 .050  0.663  7.30 20.00 4000. .575 0.278  0.014
  20 0.0621 1.62 1.30 1.032 .390 .394 1.044 1.60 1.308 5.06 .326 0.068 .060  0.641  7.30 10.00  933. .702 0.337  0.059
  30 0.0674 1.56 1.39 0.908 .342 .370 0.980 1.67 1.174 4.86 .304 0.066 .060  0.518  7.37  3.00   81. .510 0.524  0.665

1 AVE 0.0637 1.39      1.208      .405       1.61       5.02 .325       .060  0.607  7.32              .529 0.379  0.245

  40 0.0608 1.61 1.60 0.661 .249 .379 1.004 1.65 1.215 4.83 .268 0.111 .047  0.481  7.35  3.00   47. .531 0.598  1.152
  50 0.0581 1.83 1.67 0.590 .223 .332 0.879 1.67 1.113 4.80 .252 0.080 .040  0.450  7.34  2.00   55. .551 0.575  0.902
  60 0.0610 1.33 1.59 0.668 .252 .328 0.868 1.74 1.022 4.74 .253 0.074 .040  0.380  7.37  3.00   71. .453 0.540  0.721
  70 0.0813 1.84 1.67 0.590 .223 .403 1.067 1.68 1.212 4.85 .362 0.040 .007  0.644  7.38  2.00   55. .504 0.575  1.045
  80 0.1026 1.02 1.40 0.897 .338 .454 1.203 1.60 1.408 4.77 .433 0.021 .093  0.718  7.32  3.00  167. .504 0.450  0.356
  90 0.1027 1.66 1.51 0.758 .285 .479 1.270 1.55 1.513 4.75 .429 0.050 .100  0.825  7.36  1.00   61. .524 0.560  0.997
 100 0.1060 1.28 1.32 1.006 .380 .449 1.191 1.60 1.401 4.76 .445 0.004 .093  0.762  7.33  2.00   90. .468 0.512  0.559

2 AVE 0.0818 1.51      0.738      .403       1.64       4.79 .349       .060  0.609  7.35              .519 0.544  0.832

 110 0.0958 1.93 1.62 0.633 .239 .421 1.115 1.63 1.310 4.71 .390 0.031 .087  0.710  7.33  0.0    90. .336 0.512  0.539
 120 0.0768 1.70 1.64 0.620 .234 .361 0.957 1.65 1.173 4.75 .321 0.040 .060  0.460  7.32  0.0   115. .407 0.465  0.457
 130 0.0752 1.49 1.84 0.441 .166 .383 1.016 1.74 1.107 4.67 .297 0.086 .020  0.547  7.37  0.0    64. .329 0.508  1.307
 140 0.0781 1.43 1.67 0.583 .220 .376 0.996 1.70 1.145 4.70 .316 0.060 .050  0.549  7.33  0.0    52. .405 0.543  1.066
 150 0.0806 1.46 1.60 0.660 .249 .419 1.111 1.64 1.294 4.61 .307 0.112 .073  0.668  7.38  0.0    41. .525 0.520  1.411
 160 0.0835 1.55 1.48 0.786 .297 .405 1.072 1.64 1.269 4.67 .331 0.073 .080  0.729  7.30  0.0    45. .561 0.505  1.253
 170 0.0762 1.62 1.54 0.716 .270 .409 1.084 1.63 1.291 4.67 .303 0.106 .067  0.700  7.39  0.0    37. .536 0.538  1.525
 180 0.0738 1.89 1.69 0.570 .215 .410 1.087 1.63 1.293 4.66 .295 0.115 .040  0.653  7.37  0.0    35. .590 0.648  1.514
 190 0.0697 1.18 1.56 0.694 .262 .344 0.913 1.71 1.084 4.61 .266 0.078 .053  0.641  7.43  0.0    45. .758 0.605  1.159
 200 0.0709 1.17 1.41 0.873 .330 .346 0.917 1.74 1.050 4.46 .247 0.099 .067  0.676  7.33  0.0    58. .730 0.567  0.918

3 AVE 0.0781 1.58      0.658      .388       1.67       4.65 .307       .061  0.633  7.35              .528 0.587  1.135
 PROFILE
      0.0772 1.53      0.769      .396       1.65       4.75 .325       .060  0.621  7.35              .540 0.541  0.895
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Table 16 (Cont.)

MONT SITE 7 DATE: 8/10/74 SAMPLE NO. 1 VEGETATION TYPE: Silver sagebrush-Western wheatgrass-Needle and thread

H	DPTH	SM	VOL WT	VOL AVE	FVR	VMC	SMC	TVR	G/CC	SVR	FF	AMC	CMC	LS	EC	PH	ROOTS	ET	TRAV	EK	IR
	10	0.0500	1.17	0.0	1.274	.481	.410	1.046	1.58	1.365	5.02	.255	0.155	.033	0.689	7.33	15.00	200.	.801	0.435	0.274
	20	0.0526	1.46	1.31	1.015	.383	.385	1.020	1.68	1.184	5.08	.282	0.103	.040	0.595	7.31	10.00	117.	.906	0.484	0.475
	30	0.0556	1.21	1.28	1.073	.405	.363	0.951	1.67	1.162	4.76	.233	0.129	.020	0.437	7.40	6.00	51.	.835	0.586	1.038
	40	0.0540	1.44	1.37	0.936	.353	.375	0.993	1.65	1.168	4.55	.260	0.115	.040	0.521	7.35	8.00	103.	.952	0.497	0.531
	50	0.0572	1.28	1.31	1.025	.387	.390	1.034	1.66	1.219	4.44	.275	0.116	.047	0.497	7.34	8.00	86.	.945	0.517	0.545
	60	0.0582	1.29	1.34	0.983	.371	.378	1.001	1.65	1.213	4.64	.259	0.118	.047	0.485	7.31	4.00	109.	.931	0.491	0.495
1	AVE	0.0546	1.31		1.051		.383		1.65		4.93	.261		.038	0.537	7.34			.895	0.501	0.577
	70	0.0555	1.46	1.35	0.969	.366	.396	1.049	1.61	1.297	4.56	.271	0.125	.040	0.518	7.30	7.00	56.	.973	0.572	0.973
	80	0.0505	1.80	1.52	0.747	.282	.356	0.942	1.67	1.151	4.94	.241	0.115	.033	0.472	7.29	7.00	42.	.926	0.515	1.244
	90	0.0330	1.43	1.57	0.693	.261	.200	0.530	1.79	0.787	4.68	.151	0.050	.0	0.360	7.30	3.00	18.	.555	0.797	1.955
	100	0.0573	1.27	1.50	0.764	.288	.364	0.954	1.71	1.114	4.69	.264	0.100	.040	0.919	7.24	3.00	46.	.925	0.501	1.152
	110	0.0625	1.40	1.37	0.933	.352	.342	0.906	1.68	1.115	4.70	.253	0.088	.040	1.269	7.28	1.00	32.	.968	0.564	1.595
	120	0.0583	1.41	1.36	0.943	.355	.257	0.681	1.79	0.861	4.70	.235	0.022	.020	1.078	7.26	2.00	31.	.895	0.571	1.407
	130	0.0595	1.31	1.38	0.926	.349	.254	0.674	1.81	0.836	4.66	.234	0.020	.013	0.887	7.14	1.00	12.	.638	0.927	3.539
2	AVE	0.0538	1.44		0.854		.310		1.72		4.62	.235		.027	0.766	7.26			.855	0.593	1.715
	140	0.0558	1.53	1.42	0.869	.328	.258	0.683	1.74	0.915	4.61	.213	0.045	.013	0.899	7.20	0.0	15.	.790	0.850	2.836
	150	0.0530	1.49	1.44	0.836	.316	.275	0.729	1.76	0.920	4.57	.216	0.059	.013	1.096	7.15	0.0	12.	.542	0.927	3.777
	160	0.0572	1.62	1.55	0.713	.269	.266	0.705	1.64	0.823	4.66	.225	0.041	.013	1.006	7.20	1.00	28.	.590	0.591	1.649
	170	0.0497	1.64	1.58	0.674	.254	.237	0.628	1.79	0.841	4.46	.174	0.063	.007	0.806	7.35	1.00	13.	.593	0.898	3.139
	180	0.0511	1.53	1.60	0.661	.249	.252	0.667	1.78	0.863	4.32	.166	0.086	.007	0.799	7.30	0.0	8.	.592	1.107	5.337
	190	0.0535	1.51	1.56	0.701	.265	.252	0.669	1.80	0.844	4.44	.186	0.067	.013	0.723	7.25	0.0	8.	.614	1.107	5.410
	200	0.0550	1.45	1.50	0.771	.291	.252	0.657	1.81	0.833	4.63	.212	0.040	.013	0.833	7.17	0.0	6.	.915	1.107	5.424
	210	0.0584	1.49	1.49	0.783	.296	.304	0.805	1.79	0.941	4.21	.179	0.124	.027	0.929	7.21	0.0	11.	.851	0.950	4.498
	220	0.0549	1.62	1.52	0.741	.280	.266	0.705	1.79	0.885	4.39	.165	0.081	.007	0.753	7.18	0.0	12.	.580	0.927	3.720
	230	0.0517	1.47	1.53	0.735	.278	.263	0.697	1.78	0.880	4.08	.149	0.114	.013	0.708	7.23	0.0	5.	.594	1.431	8.542
	240	0.0669	1.41	1.50	0.769	.290	.310	0.823	1.71	1.031	4.27	.212	0.098	.027	1.008	7.20	0.0	15.	.942	0.850	3.222
	250	0.0496	1.78	1.55	0.707	.267	.260	0.690	1.77	0.867	4.14	.147	0.113	.013	0.676	7.23	0.0	9.	.725	1.049	4.951
	250	0.0461	1.51	1.57	0.692	.261	.292	0.774	1.81	0.892	4.10	.134	0.158	.007	0.633	7.23	0.0	5.	.755	1.431	9.765
	270	0.0540	1.51	1.60	0.657	.248	.230	0.609	1.76	0.852	4.34	.177	0.053	.020	0.663	7.20	0.0	15.	.899	0.850	2.517
3	AVE	0.0544	1.54		0.736		.266		1.79		4.37	.184		.014	0.824	7.22			.742	1.013	4.648
	280	0.0558	1.50	1.51	0.759	.286	.270	0.715	1.79	0.880	4.17	.168	0.101	.013	0.735	7.20	0.0	13.	.724	0.898	3.489
4	AVE	0.0558	1.50		0.759		.270		1.79		4.17	.168		.013	0.735	7.20			.724	0.898	3.489
	PROFILE	0.0544	1.46		0.834		.302		1.74		4.60	.213		.022	0.750	7.26			.903	0.819	3.001

Table 16 (Cont.)

MONT SITE 8 DATE: 8/10/74 SAMPLE NO. 1 VEGETATION TYPE: Big sagebrush-Bluebunch wheatgrass-Blue grama

M DPTH	SM	VOL WT	VOL AVE	FVR	VMC	SMC	TVR	G/CC	SVR	PF	AMC	CMC	LS	EC	PH	ROOTS	ET	TRAN	EK	IR
10	0.0567	1.11	0.0	1.379	.520	.337	0.894	1.73	1.049	5.10	.308	0.029	.073	0.526	7.25	13.00	98.	.779	0.502	0.530
20	0.0899	1.32	1.22	1.180	.445	.461	1.222	1.61	1.405	4.63	.358	0.104	.057	0.899	7.23	10.00	97.	.723	0.503	0.625
1 AVE	0.0733	1.22		1.279		.399		1.67		4.89	.333		.080	0.713	7.24			.751	0.503	0.577
30	0.0842	1.50	1.31	1.022	.386	.414	1.096	1.67	1.243	4.39	.282	0.131	.087	0.718	7.22	2.00	270.	.545	0.411	0.215
40	0.0702	2.07	1.63	0.625	.236	.380	1.007	1.70	1.151	4.44	.243	0.137	.080	0.696	7.13	7.00	170.	.899	0.448	0.328
50	0.0746	1.65	1.74	0.522	.197	.465	1.233	1.64	1.368	4.51	.282	0.183	.133	0.877	7.11	3.00	1440.	.797	0.317	0.043
50	0.0678	1.61	1.78	0.489	.185	.424	1.123	1.68	1.245	4.35	.224	0.200	.080	1.042	7.08	2.00	987.	.951	0.334	0.050
2 AVE	0.0752	1.71		0.665		.421		1.67		4.42	.258		.095	0.833	7.13			.923	0.378	0.152
70	0.0621	1.94	1.73	0.528	.199	.420	1.113	1.73	1.175	4.35	.206	0.214	.073	1.689	7.08	1.00	1069.	.931	0.329	0.056
80	0.0781	1.79	1.78	0.486	.184	.377	0.999	1.77	1.062	4.15	.233	0.144	.047	3.165	6.96	1.00	373.	.857	0.369	0.155
90	0.0895	1.63	1.79	0.483	.182	.399	1.058	1.73	1.143	4.02	.251	0.148	.080	3.846	6.95	1.00	1314.	.819	0.321	0.045
100	0.0783	1.47	1.63	0.624	.235	.365	0.957	1.74	1.079	3.93	.202	0.163	.053	3.623	6.90	1.00	58.	.890	0.567	0.959
110	0.1027	2.06	1.72	0.542	.205	.402	1.065	1.77	1.099	4.02	.288	0.114	.073	4.032	6.97	1.00	350.	.927	0.393	0.173
120	0.1066	1.57	1.70	0.559	.211	.478	1.255	1.65	1.373	3.94	.294	0.184	.100	4.032	6.87	0.0	1333.	.919	0.320	0.049
130	0.0786	1.66	1.76	0.503	.190	.391	1.036	1.74	1.118	4.01	.219	0.171	.053	3.425	6.90	0.0	1040.	.929	0.333	0.054
140	0.0826	1.80	1.68	0.578	.218	.401	1.062	1.75	1.121	4.14	.245	0.156	.057	3.472	6.98	0.0	1337.	.975	0.320	0.045
150	0.0817	1.25	1.57	0.685	.259	.326	0.864	1.75	1.008	4.03	.236	0.090	.027	3.247	6.90	0.0	938.	.917	0.336	0.055
3 AVE	0.0845	1.69		0.554		.395		1.74		4.07	.242		.064	3.392	6.95			.896	0.368	0.177
150	0.0720	1.88	1.64	0.612	.231	.326	0.864	1.76	0.997	3.95	.197	0.129	.013	2.500	6.93	0.0	971.	.848	0.335	0.053
4 AVE	0.0720	1.88		0.612		.326		1.76		3.95	.197		.013	2.500	6.93			.848	0.335	0.053
PROFILE	0.0800	1.65		0.676		.398		1.71		4.25	.254		.070	2.362	7.03			.856	0.385	0.215

MONT SITE 9 DATE: 8/10/74 SAMPLE NO. 1 VEGETATION TYPE: Prairie sandreed

M DPTH	SM	VOL WT	VOL AVE	FVR	VMC	SMC	TVR	G/CC	SVR	PF	AMC	CMC	LS	EC	PH	ROOTS	ET	TRAN	EK	IR
10	0.0271	0.93	0.0	1.849	.698	.379	1.005	1.65	1.215	4.52	.098	0.281	.013	0.143	7.52	30.00	117.	.947	0.484	0.460
20	0.0809	1.40	1.17	1.272	.480	.393	1.041	1.62	1.278	3.62	.208	0.185	.047	0.385	7.43	10.00	143.	.903	0.464	0.382
30	0.0913	1.37	1.23	1.149	.434	.430	1.138	1.62	1.339	3.70	.224	0.206	.047	0.463	7.44	20.00	38.	.874	0.533	1.529
40	0.0599	1.78	1.52	0.747	.282	.333	0.883	1.70	1.078	3.75	.150	0.184	.027	0.368	7.45	25.00	25.	.951	0.715	2.028
1 AVE	0.0648	1.37		1.254		.384		1.65		3.95	.170		.033	0.344	7.46			.896	0.574	1.100
50	0.0578	1.73	1.63	0.629	.237	.229	0.607	1.77	0.840	3.07	.113	0.116	.0	0.245	7.20	8.00	15.	.579	0.850	2.525
50	0.0541	1.42	1.65	0.610	.230	.168	0.445	1.75	0.759	2.26	.085	0.083	.0	0.181	7.34	9.00	5.	.536	1.431	5.034
70	0.0682	1.57	1.56	0.681	.257	.210	0.555	1.80	0.761	2.02	.101	0.109	.0	0.305	7.35	8.00	5.	.372	1.431	7.440
80	0.0740	1.50	1.50	0.769	.290	.224	0.594	1.75	0.854	2.07	.111	0.113	.007	0.429	7.19	6.00	9.	.565	1.049	4.245
90	0.1138	1.94	1.67	0.586	.221	.290	0.759	1.75	0.954	1.54	.151	0.134	.013	0.521	7.16	5.00	29.	.350	0.564	1.520
2 AVE	0.0736	1.63		0.655		.224		1.77		2.19	.112		.004	0.336	7.25			.500	1.069	4.393
100	0.2294	1.43	1.62	0.632	.238	.428	1.134	1.66	1.280	1.81	.323	0.105	.013	1.634	6.90	3.00	1440.	.900	0.317	0.041
110	0.3225	1.29	1.55	0.706	.266	.942	2.496	1.40	2.675	3.56	.749	0.193	****	2.778	6.90	2.00	1440.	.935	0.317	0.055
120	0.2027	1.28	1.33	0.989	.373	.541	1.432	1.60	1.552	3.33	.434	0.107	.127	4.464	6.89	2.00	847.	.981	0.342	0.079
130	0.2262	1.46	1.34	0.975	.368	.569	1.507	1.61	1.582	3.06	.446	0.123	.113	4.717	6.90	1.00	43.	.875	0.509	0.749
3 AVE	0.2452	1.36		0.825		.620		1.57		2.94	.488		.313	3.398	6.90			.923	0.371	0.231
140	0.1774	1.70	1.48	0.792	.299	.614	1.628	1.60	1.674	3.24	.368	0.246	.120	3.571	6.90	1.00	1440.	.974	0.317	0.050
150	0.1648	2.01	1.72	0.538	.203	.604	1.601	1.55	1.725	3.43	.366	0.238	.093	3.623	6.90	1.00	1440.	.993	0.317	0.048
150	0.1649	2.05	1.92	0.381	.144	.678	1.798	1.53	1.907	3.26	.347	0.331	.133	3.049	6.93	0.0	1440.	.958	0.317	0.051
4 AVE	0.1691	1.92		0.570		.632		1.56		3.32	.361		.116	3.414	6.91			.941	0.317	0.050
PROFILE	0.1322	1.55		0.832		.439		1.65		3.03	.267		.110	1.681	7.15			.819	0.536	1.715

Table 16 (Cont.)

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 MONT   SITE   10  DATE: 8/10/74   SAMPLE NO. 1   VEGETATION TYPE: Blue grama-Big sagebrush
               VOL    VOL
H DPTH   SM    WT     AVE   FVR    VMC   SMC   TVR   G/CC   SVR    PF    AMC   CMC    LS     EC     PH  ROOTS    ET  TRAN   EK     IR

   10 0.0221 1.03 0.0  1.585 .598 .237 0.627 1.80 0.821 4.12 .065 0.172 .007  0.400  7.20  8.00   39. .957 0.529  1.044
   20 0.0405 1.99 1.51 0.759 .287 .298 0.791 1.75 0.965 5.05 .211 0.087 .027  1.068  7.08 10.00   77. .901 0.530  0.623
   30 0.0651 1.33 1.45 0.832 .314 .376 0.996 1.72 1.120 4.82 .286 0.090 .080  2.066  7.08  5.00  112. .959 0.483  0.501

1 AVE 0.0426 1.45      1.059      .304       1.76       4.65 .187       .038  1.178  7.12                .905 0.549  0.723

   40 0.0725 2.55 1.96 0.355 .134 .334 0.885 1.77 0.997 4.64 .282 0.052 .053  3.521  7.55  3.00   84. .965 0.520  0.625
   50 0.0772 1.48 1.79 0.484 .183 .356 0.944 1.75 1.053 4.07 .221 0.135 .053  3.846  8.20  1.00   68. .963 0.545  0.307
   60 0.0752 1.80 1.94 0.364 .138 .340 0.900 1.80 0.972 3.84 .199 0.141 .053  3.205  8.33  1.00 1021. .862 0.332  0.053

2 AVE 0.0750 1.94      0.401      .343       1.77       4.20 .234       .053  3.524  8.06                .937 0.465  0.495

   70 0.0761 2.04 1.77 0.497 .188 .367 0.472 1.69 1.143 3.94 .206 0.161 .047  3.521  8.40  0.0   143. .952 0.454  0.378
   80 0.0600 1.51 1.78 0.487 .184 .274 0.727 1.83 0.845 4.13 .177 0.098 .020  2.907  8.49  0.0    84. .785 0.520  0.560
   90 0.1114 1.90 1.82 0.458 .173 .637 1.698 1.55 1.799 4.00 .310 0.327 .120  3.247  8.72  0.0  1440. .729 0.317  0.050
  100 0.1602 1.37 1.60 0.660 .249 .786 2.083 1.50 2.155 3.74 .399 0.387 .147  4.808  8.52  0.0    70. .985 0.542  1.123
  110 0.1414 2.17 1.82 0.460 .174 .591 1.567 1.55 1.721 3.70 .347 0.244 .087  3.731  8.61  0.0  1440. .768 0.317  0.047

3 AVE 0.1098 1.80      0.512      .531       1.62       3.90 .288       .084  3.643  8.55                .844 0.432  0.432

  120 0.1435 1.98 1.84 0.440 .166 .656 1.739 1.51 1.907 3.93 .395 0.262 .107  4.032  8.45  0.0  1440. .534 0.317  0.049
  130 0.1828 1.85 2.00 0.324 .122 .663 1.757 1.52 1.900 3.90 .479 0.184 .107  4.808  8.40  0.0  1440. .578 0.317  0.050

4 AVE 0.1631 1.92      0.382      .660       1.51       3.92 .437       .107  4.420  8.42                .606 0.317  0.049
 PROFILE
      0.0945 1.77      0.593      .455       1.67       4.15 .275       .070  3.166  8.09                .843 0.449  0.455

 MONT   SITE   11  DATE: 8/10/74   SAMPLE NO. 1   VEGETATION TYPE: Blue grama-Western wheatgrass
               VOL    VOL
H DPTH   SM    WT     AVE   FVR    VMC   SMC   TVR   G/CC   SVR    PF    AMC   CMC    LS     EC     PH  ROOTS    ET  TRAN   EK     IR

   10 0.0503 1.42 0.0  0.862 .325 .359 0.952 1.64 1.196 5.04 .260 0.099 .047  0.377  7.05 15.00  216. .902 0.428  0.240
   20 0.0603 1.44 1.43 0.851 .321 .336 0.891 1.74 1.035 3.85 .157 0.179 .040  0.346  7.86 10.00   73. .928 0.537  0.715
   30 0.0650 1.50 1.45 0.821 .310 .330 0.876 1.76 1.003 4.21 .200 0.131 .047  0.774  8.20  8.00  125. .918 0.477  0.417

1 AVE 0.0595 1.45      0.845      .342       1.71       4.37 .206       .044  0.499  7.70                .863 0.481  0.458

   40 0.0630 2.01 1.65 0.604 .228 .316 0.838 1.77 0.971 3.91 .168 0.148 .033  1.042  8.33  9.00  170. .971 0.448  0.298
   50 0.0680 1.64 1.72 0.542 .205 .278 0.737 1.81 0.871 3.73 .169 0.110 .027  1.250  8.50  7.00  156. .970 0.455  0.301
   60 0.0788 1.83 1.83 0.450 .170 .266 0.704 1.84 0.823 3.49 .179 0.087 .027  1.953  8.50  5.00  230. .954 0.423  0.200
   70 0.0801 1.73 1.73 0.529 .200 .254 0.673 1.87 0.777 3.31 .170 0.084 .013  2.083  8.53  5.00  259. .957 0.414  0.175

2 AVE 0.0725 1.80      0.531      .278       1.82       3.61 .171       .025  1.582  8.51                .963 0.435  0.244

   80 0.0901 1.62 1.73 0.535 .202 .254 0.674 1.96 0.695 3.10 .179 0.075 .013  2.358  8.53  1.00  215. .820 0.429  0.220
   90 0.0852 1.58 1.64 0.613 .231 .233 0.617 1.97 0.655 3.26 .185 0.048 .020  2.273  8.40  1.00  137. .750 0.468  0.324
  100 0.0747 1.42 1.54 0.722 .272 .247 0.654 1.88 0.758 3.07 .147 0.100 .007  2.033  8.35  2.00  165. .927 0.451  0.259
  110 0.1132 2.08 1.69 0.567 .214 .220 0.582 1.94 0.665 3.08 .223 -.003 .007  2.119  8.45  2.00   70. .527 0.542  0.595
  120 0.1312 1.86 1.78 0.485 .183 .248 0.657 1.95 0.696 3.03 .255 -.007 .020  2.475  8.35  0.0    67. .424 0.548  0.590
  130 0.1297 1.50 1.81 0.464 .175 .221 0.585 2.02 0.601 2.99 .248 -.028 .0    2.101  8.24  0.0    58. .340 0.567  0.749
  140 0.1283 1.64 1.67 0.591 .223 .211 0.558 2.06 0.557 3.13 .257 -.047 .0    2.066  8.30  0.0    92. .357 0.509  0.454
  150 0.1250 1.78 1.64 0.618 .233 .203 0.538 2.02 0.578 3.32 .267 -.064 .0    1.773  8.20  0.0   119. .325 0.452  0.342
  160 0.1127 2.03 1.82 0.459 .173 .192 0.510 2.05 0.541 3.05 .220 -.028 .0    1.667  8.23  0.0   130. .337 0.473  0.304

3 AVE 0.1103 1.72      0.562      .225       1.98       3.11 .220       .007  2.096  8.34                .534 0.496  0.440
 PROFILE
      0.0912 1.69      0.607      .260       1.89       3.47 .205       .019  1.668  8.26                .707 0.478  0.394
```

Table 16 (Cont.)

```
 MONT  SITE  12  DATE: 8/10/74  SAMPLE NO. 1  VEGETATION TYPE: Ponderosa pine-Bluebunch wheatgrass
                 VOL    VOL
M DPTH   SM      WT     AVE   FVR    VMC   SMC   TVR   G/CC  SVR    FF   AMC   CMC    LS     EC     PH  ROOTS    ET  TRAN   EK     IR

    10 0.0572 1.08 0.0   1.456 .549 .395 1.046 1.64 1.253 4.50 .205 0.190 .020  0.500  7.03  5.00  515. .507 0.369  0.107
    20 0.0728 1.04 1.06  1.505 .568 .356 0.943 1.73 1.077 4.29 .233 0.123 .013  0.370  6.96 10.00   51. .557 0.585  1.057
    30 0.0522 1.38 1.17  1.274 .481 .323 0.856 1.74 1.015 4.08 .151 0.172 .027  0.250  7.57  7.00   73. .586 0.537  0.594

1 AVE  0.0607 1.17       1.411      .358       1.70       4.29 .196       .020  0.373  7.19              .717 0.497  0.519

    40 0.0372 1.51 1.31  1.023 .386 .301 0.796 1.78 0.935 4.38 .124 0.176 .013  0.186  7.61  3.00   50. .932 0.589  0.945
    50 0.0346 1.71 1.54  0.726 .274 .302 0.801 1.78 0.939 4.16 .103 0.199 .020  0.189  7.61  3.00   41. .908 0.620  1.203
    60 0.0491 2.46 1.90  0.398 .150 .311 0.825 1.81 0.920 3.99 .136 0.175 .013  0.259  8.00  2.00   76. .930 0.532  0.672
    70 0.0685 1.51 1.90  0.398 .150 .252 0.748 1.83 0.857 3.57 .160 0.122 .013  0.331  8.32  1.00  190. .865 0.439  0.253
    80 0.0612 1.81 1.93  0.374 .141 .278 0.736 1.79 0.892 3.50 .139 0.139 .0    0.487  8.52  1.00  313. .742 0.401  0.149
    90 0.0627 2.46 1.93  0.373 .141 .302 0.801 1.82 0.896 3.70 .154 0.148 .007  0.478  8.23  3.00  200. .954 0.435  0.251

2 AVE  0.0522 1.91       0.549      .296       1.80       3.68 .136       .011  0.322  8.05              .892 0.502  0.595

   100 0.0704 1.72 2.00  0.326 .123 .305 0.807 1.83 0.889 3.64 .183 0.122 .013  0.735  8.38  1.00  315. .971 0.400  0.162
   110 0.0851 2.07 2.08  0.272 .103 .301 0.797 1.77 0.948 3.48 .192 0.109 .020  1.282  8.40  1.00  400. .979 0.384  0.122
   120 0.0701 2.60 2.13  0.244 .092 .280 0.741 1.80 0.884 3.55 .162 0.117 .027  0.825  8.72  1.00  277. .964 0.409  0.169

3 AVE  0.0752 2.13       0.281      .295       1.80       3.62 .179       .020  0.947  8.33              .938 0.398  0.151
 PROFILE
       0.0601 1.78       0.697      .311       1.78       3.92 .162       .016  0.491  7.90              .860 0.475  0.485
```

4=That portion of the soil profile with no evidence of live roots. This usually represents the top of the C horizon.

DPTH=Sampling depth in centimetres. The depth reported is the depth in centimetres to the bottom of the sample.

SM=Soil Moisture or moisture content of the sample in grams of water per gram of dry soil. Richards et al. (1954), Method 26 or ASTM (1958) Designation: D 698-57T paragraph 11 except that results are not converted to percents.

VOL WT=Bulk density or apparent volume-weight is grams per cubic centimetre. Computed as the dry weight of the soil sample in grams divided by the product of the mean cross sectional area of the augered hole and the sampling depth increment.

VOL (AVE)=Average bulk density or average apparent volume-weight in grams per cubic centimetre, computed as a moving average. Each figure is the average of three consecutive figures in the preceding column: This computing technique reduces the variability introduced when the auger does not retain the same volume of soil even though the depth to which it is driven is precisely controlled.

FVR=Field Void Ratio - The ratio of the volume of voids to the volume of solids. Computed from the average bulk density by assuming that the density of the solids is 2.65 grams per cubic centimetre. The formula is $FVR=d_S/d_B-1$ where d_S=specific gravity of soil particles and d_B=volume weight or bulk density of the soil in situ (Krynine, 1947, p. 45).

VMC=Voids moisture capacity. The weight of water in grams that would fill the voids in a unit volume (1cc) of soil if the soil mass were confined so that the field bulk density is maintained. Computed as: VMC=FVR/2.65 (Krynine, 1947, p. 32).

SMC=Saturation moisture capacity. The maximum moisture that a sample will absorb under free-swell, disturbed conditions; the moisture content at ultimate hydration. Richards et al. (1954), method 2 or ASTM (1958) Designation D 426-39.

TVR=Void ratio for completely saturated sample is computed as 2.65 times SMC.

G/cc=Total density of saturated paste. Determined by weighing 100 cubic centimetres of saturated paste after tapping the container on a solid surface to remove the larger air bubbles.

SVR=Saturated void ratio. Void ratio of saturated paste computed from SMC and total density of saturated paste. This void ratio includes minute bubbles of air retained in the paste.

pF=The moisture retention force existing in the soil at the time of sampling. Reported as the logarithm of the height of a column of water supported by an equivalent force. pF is measured using the method of McQueen and Miller (1968).

AMC=Adsorbed moisture capacity. This represents the moisture content in grams required to satisfy all of the molecular adsorptive forces exerted by a gram of soil particles. Computed as AMC=-6.25 SM/(pF-6.25). This value is the intercept of the adsorbed segment of the moisture characteristic with the X (or zero pF) axis.

CMC=Capillary moisture capacity. Computed as SMC-AMC. Where this value is negative it means that the soil moisture characteristic probably can have no capillary segment because the pores are too small.

LS=Linear shrinkage. Ratio of the change in diameter of a cylindrical pat of saturated paste during desiccation to the original diameter of the saturated pat.

EC=Electrical conductivity of saturated paste. Richards et al. (1954), method 5 except that a two-prong stainless steel probe is used in place of the Bureau of Soils electrode cup.

PH=The negative logarithm of the hydrogen ion concentration in the saturated paste. Richards et al., method 21a.

ROOTS=Relative concentration of roots. The root material retained on a 60-mesh sieve in a wet sieving process was examined and the relative concentration within the profile was estimated. The concentration of roots in the second sample (10 to 20 cm) was given a value of 10 and the other samples were given relative numbers. Where roots are reported as 0.0 for all depths at a site the estimation was not made.

ET=Erosion time (minutes). Time in minutes required to erode the sample after it has been saturated, puddled, placed in a cylindrical container, allowed to air dry, removed from its container and subjected to an erosive force that simulates a flowing stream with a velocity of 0.58 meter per second measured about 2 cm from the eroding surface.

TRAN=The ratio of transportable to nontransportable particles. A 60-mesh (0.25 mm) sieve has been arbitrarily chosen to define the boundary between suspended and bedload material. Those particles smaller than 0.25 mm can be suspended in a moderately turbulent stream. Particles larger than 0.25 mm will usually be bedload.

EK=Erodibility constant. Computed as the reciprocal of the logarithm of the erosion time. $EK=1/\log_{10}ET$. This relationship is discontinuous at ET=1 and because short erosion times are difficult to measure accurately, for samples where ET approached 1 minute, a value of 2 minutes was arbitrarily assigned. Also, when a sample had not disintegrated after 24 hours in the erosion test device it was removed and arbitrarily assigned a time of 24 hours.

NOTE: EK is similar in form to the K value defined by Wischmeier et al., for use in the universal soil-loss equation. However, it should not be considered as a replacement or duplication because it is derived from erosion tests instead of grain size data. Parallel tests have not been conducted to define the possible relationships between EK and K.

IR=Infiltration rate. Computed from the dimensions of the saturated soil pat and the erosion time by assuming that when erosion is completed sufficient water has entered the pat to completely saturate it. When an erosion pat is reinforced with roots or gravel particles in a clay matrix its ET may be extended and the computed IR may be too small. IR, as reported, should be considered as a minimum infiltration rate in cubic centimetres per square centimetre per hour.

Discussion

An objective of this study was to define the hydrologic characteristics of soils associated with vegetation types existing on sites proposed for strip mining of coal. Many hydrologic properties of soils are not constant but can change one or two orders of magnitude under natural conditions. Greater changes can be expected during the disturbance of mining operations.

One property of a soil that will not change appreciably is its specific surface. This can be changed by weathering or by crushing and grinding but these changes are slow. Hydrologic characteristics that are functions of specific surface can be defined for individual soil samples or for mixtures of soils. The adsorbed film segment of the moisture retention characteristic of a soil is a direct function of the specific surface and can be defined by a single parameter AMC (adsorbed moisture capacity). Evaporation and transpiration can be estimated from the soil moisture characteristics for the soil horizons and a knowledge of the growth patterns and moisture requirements of the plants.

Any hydrologic characteristic that is dependent on the geometry of the pore space will be changed by the disturbance of surface mining. If these characteristics are to be defined they must be defined in terms of the porosity that will exist or some parameter related to the porosity. A nomograph (figure 7) is provided to assist in making estimates of porosity and related functions. This nomograph assumes a two-phase system of soil particles and water. Where three phases are present (soil, air and water) appropriate corrections or adjustments should be made to the data or estimates. For example, when the total density is computed from the moisture content of a saturated paste it is usually higher than the measured density because of air bubbles included in the paste. A similar source of error is involved in computation of specific gravity of soil particles from shrinkage limit and shrinkage ratio (ASTM, 1958, Designation D 426-39, paragraph 10).

Void ratios are used to control compaction of soil in engineering structures. The nomograph should be useful in conversions between density data, porosities, void ratios, and saturated moisture contents.

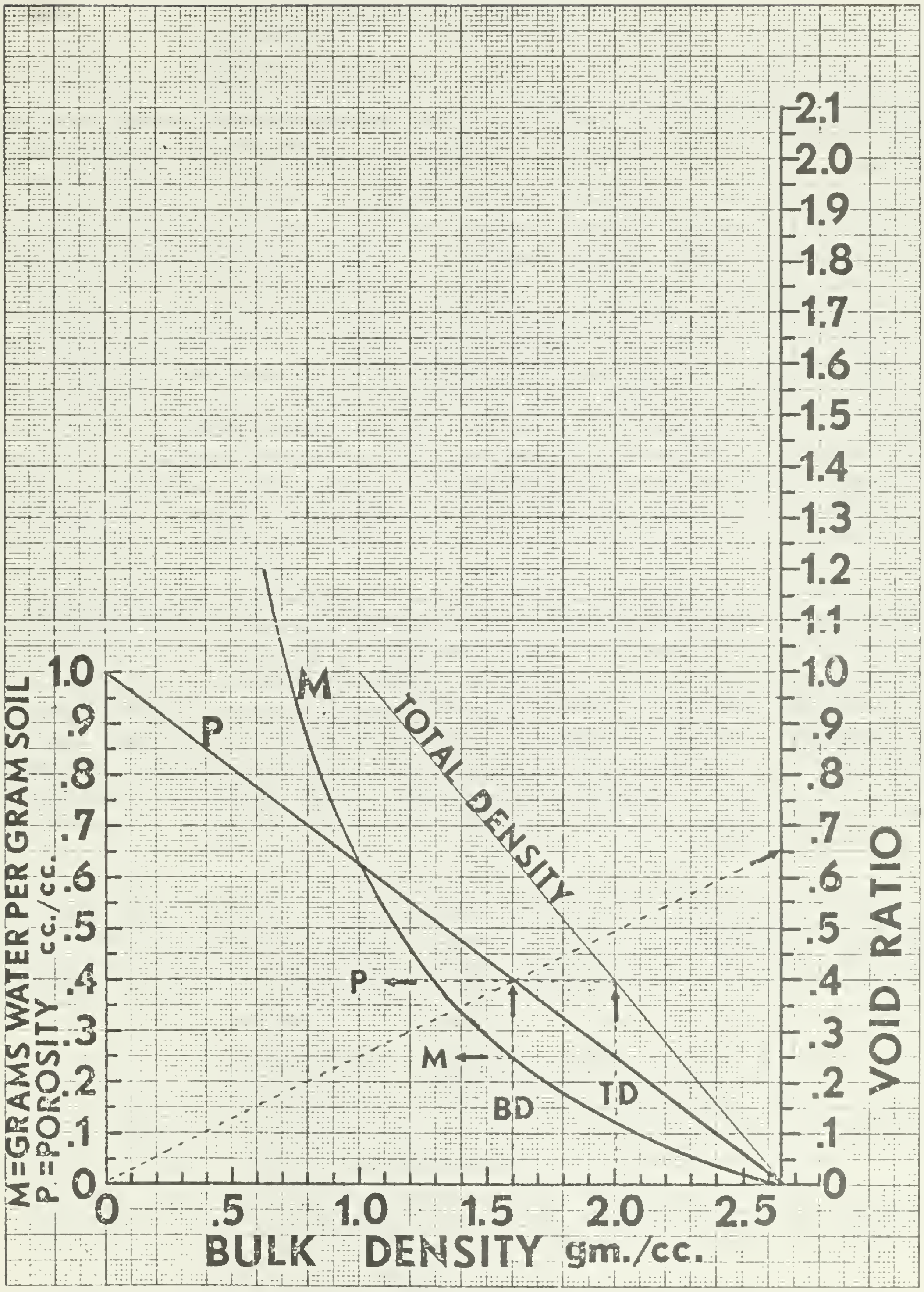

Figure 7.--Nomograph for conversion between bulk densities, porosities, saturated moisture contents and void ratios.

This nomograph can be constructed for any particle density or it can be constructed to a different scale for more accuracy.

The forces involved in erosion of soils are extremely complex and variable. Prediction of erosion rates from laboratory tests of physical properties of soils has not been successful. It is possible, however, to define relative susceptibility of soils to a given set of erosion forces by controlled tests (McQueen, 1961). For significant results, the erosion forces and the condition of the samples prior to and during the tests should simulate conditions expected in the field.

Three methods for determining soil erodibility have been combined in a laboratory test for defining the susceptibility of these soils to erosion forces. A slaking test suggested by Winterkorn (1973); rotating cylinder methods; (described by Masch et al., 1965, Akky, and Shen 1973; Arulanandan et al., 1973) and an erodibility factor (described by Wischmeier and others 1958, 1959, 1965, 1969, 1971a, 1971b and 1973) based on measurements of grain size and other physical and chemical properties. This test constitutes a direct determination of the inherent erodibility of individual soil samples.

These data can be averaged and combined to predict the erodibility of the disturbed and mixed soils. Actual erosion and sediment yield from soils will depend more upon the water available to transport the sediments than upon the erodibility (detachability) of the soils. Sand and silt particles are easily detached. Therefore, sandy soils test as highly erodible. However, infiltration may be high enough to absorb all but extrene high intensity storms so erosion and sediment production on sandy soils is usually low. Clay soils do not test as highly erodible but runoff is usually excessive so erosion and sediment yield are high.

Vegetation diminishes erosion in three ways: it intercepts raindrop impact; it impedes overland flow; and it binds soil particles together in a root network. The decrease in raindrop impact is proportional to the natural cover (table 15) but the relationship is species dependent. Impedence of overland flow is influenced by topography but it is controlled by species of plants. Grasses are extremely effective but individual trees may have little effect. The binding effect of roots is included in the erodibility test. Disturbed soils may require additional protection from erosion while vegetation is being reestablished. Overland flow can be controlled by surface treatments such as contour furrowing. Interception of raindrop impact can be provided by mulches placed on the surface and the binding effect of roots can be simulated by incorporating mulch into the soil.

A laboratory measurement of erosion rates under controlled conditions is a direct determination of the erodibility of a soil. In this study the basic principles of the rotating cylinder device and the slaking test are combined to define the susceptibility of soils to a controlled erosion force.

Sample computations

The data from individual samples presented in this report can be combined and averaged in various ways to predict how the soils will perform when mixed by the mining procedure. Data from sampling site Number 9 are used here as an example.

The 2 or B horizon of a soil is usually the prime source of moisture and nutrients for sustaining plant growth. The average soil moisture characteristic for this horizon at site 9 is illustrated in figure 8. Using the method of McQueen and Miller (1974) the adsorbed segment of the characteristic is drawn between the pF intercept at (0, 6.25) and the M intercept for the mean AMC (adsorbed moisture capacity) at (0.112, 0). The mean SMC (saturation moisture capacity) value of 0.224 is plotted at pF 0.0 and a short vertical segment is drawn. The capillary segment is drawn from the capillary limit (0, 2.9) through the field capacity value on the adsorbed segment (0.0672, 2.5). A short transition curve may be drawn between the capillary segment and the SMC line, and the structured water segment may be drawn between the oven-dry intercept at (0, 7.0) and the value of the adsorbed segment at pF 5.0 (0.0224, 5.0). The moisture characteristic for the mixed profile of site 9 is drawn by using the average AMC and SMC values for the complete profile, which are AMC=0.267 and SMC=0.439.

The change in moisture content (M) for a given change in moisture stress in the adsorbed range can be computed from: M=(AMC/6.25)(pF). For example, the available moisture storage is usually assumed to be the change in moisture content between field capacity (pF 2.5) and permanent wilting (pF 4.2). For the 2 (B) Horizon of site 9 this would be (0.112/2.65) (4.2-2.5)=0.072 gm/cc=7.2 percent. With an average bulk density of 1.63 the available storage would be $(p_B)(M_W)=M_V=(1.63)(0.072=0.117$ cc/cc. These available moisture storage values for all horizons and profiles sampled are presented in table 17. Moisture represented by the capillary segment of the characteristic may be utilized if plant roots reach the capillary fringe or if trickle irrigation is used.

The erodibility of this soil, as indicated by the EK values in table 17, is high so contour furrowing should be considered. Infiltration rates as indicated by the IR values on the mixed soil will probably exceed 2 centimetres per hour. If the contour furrows will retain 4 centimetres of precipitation, then a 2-hour storm of 4 centimetres per hour intensity could be retained. This 8 cm storm would recharge 68 centimetres of soil with the storage capacity of 0.117 cc/cc, which the 2 Horizon has, (8.0/0.117=68) or 71 centimetres of the mixed profile (8/0.0726)(1.55)=71).

The volume of pores within a soil may be defined in terms of bulk density, total density, porosity or void ratio. Three void ratios are reported for each sample. FVR (Field Void Ratio) is computed from the average volume weight as: p_s/p_B (particle density/volume weight)-1 (Krynine 1947, p. 45). The average volume-weight of the 2 Horizon of site 9 is 1.63 then the void ratio=(2.65/1.63)-1=0.626. If this soil

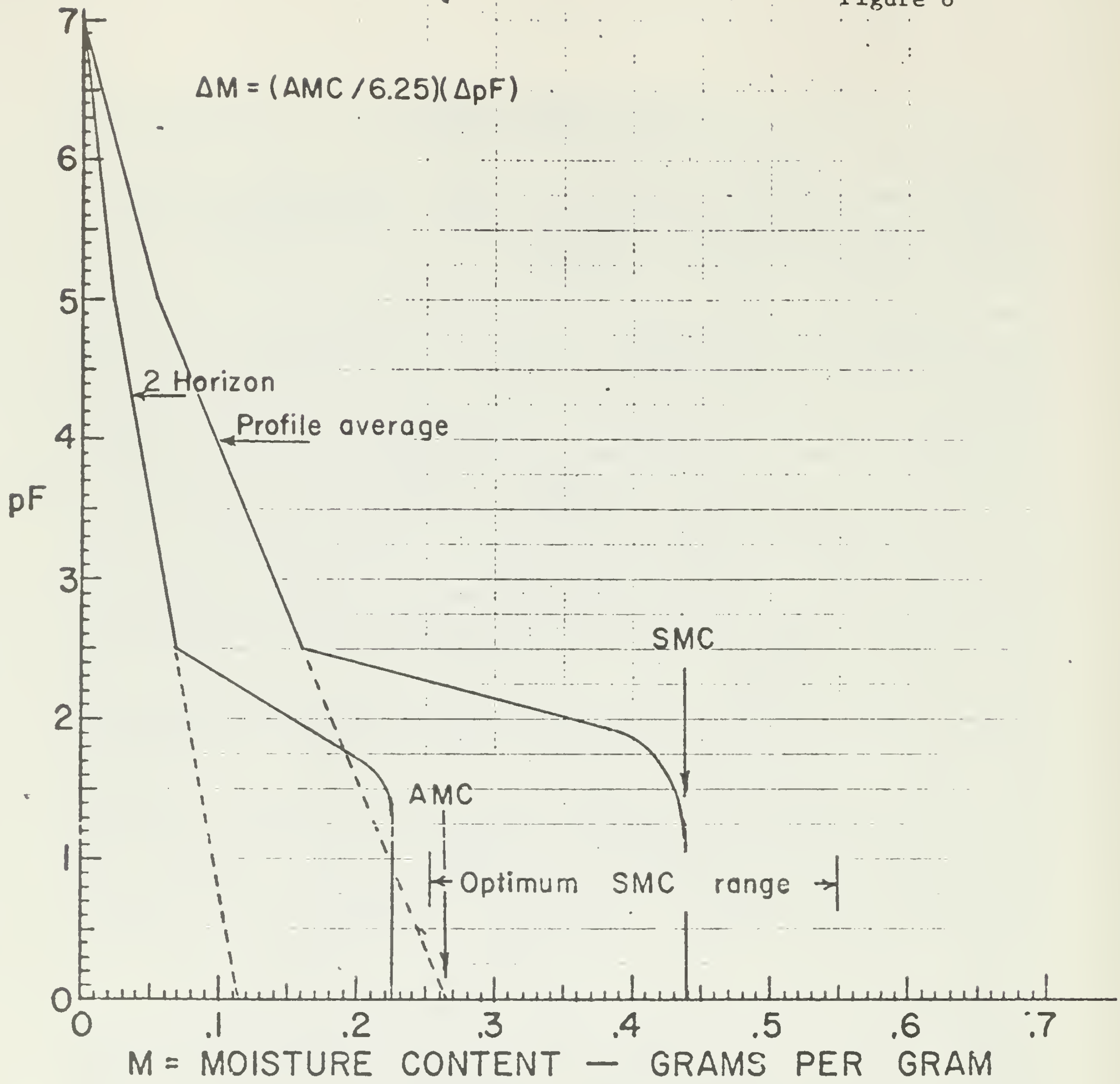

Figure 8.--Moisture characteristics for the 2 (B) horizon and the mixed profile for sampling site number 9 of the Otter Creek Coal Field near Ashland, Montana.

Table 17 Horizon and profile averages of the hydrologic data for the soils of the Otter Creek study area near Ashland, Montana

Site	Horizon	Depth cm	$\overline{F}_p$	$\overline{M}$	$\overline{SMC}$	$\overline{AMC}$	$\overline{\Delta M}$ cc/cc	$\overline{\text{Vol. wt.}}$	M use cm	$\overline{EK}$	$\overline{TR}$	$\overline{IR}$	$\overline{EC}$	Nat. cov.		S.T. Req.
1	1	30	4.01	.084	.339	.239	.116	1.21	3.49	.576	.79	1.04	0.41	----	2	2
	2	90	4.09	.088	.314	.257	.143	1.38	4.29	1.057	.48	5.41	0.23	----	2	2
	3	110	4.03	.088	.265	.247	.263	2.66	1.05	1.307	.28	7.70	0.26	----	2	2
	Profile	----	4.06	.087	.312	.250	----	1.57	8.83	.972	.53	4.64	0.28	.73	2	2
2	1	30	4.08	.076	.397	.219	.086	1.14	2.67	.425	.89	.46	0.33	----	3	2
	2	90	3.38	.086	.322	.180	.129	1.80	3.87	.492	.97	.56	0.25	----	2	2
	3	130	2.64	.121	.320	.210	.162	1.92	1.29	.462	.91	.41	1.07	----	2	2
	Profile	----	3.32	.094	.339	.198	----	1.68	7.83	.467	.93	.49	0.52	.75	2	2
3	1	10	4.60	.054	.338	.206	.084	.85	.84	.612	.89	1.17	0.83	----	2	2
	2	40	4.49	.055	.364	.194	.151	1.84	2.27	.535	.92	.74	1.16	----	3	2
	3	60	4.31	.061	.340	.198	.206	2.16	.82	.425	.84	.31	2.02	----	2	2
	4*	80	4.14	.412	.638	1.20	.398	0.78	1.59	2.253	.25	----	----	----	1	----
	1,2&3	----	4.45	.057	.352	.197	----	1.78	5.52	.511	.88	.67	1.39	.22	2	2
4	1	30	5.01	.059	.386	.309	.188	1.43	5.62	.501	.72	.66	0.50	----	3	2
	2	70	4.68	.063	.367	.254	.172	1.59	3.43	.455	.69	.37	0.52	----	3	2
	3	160	4.11	.067	.310	.194	.144	1.74	2.59	.913	.91	3.90	1.56	----	2	2
	Profile	----	4.42	.064	.339	.231	----	1.65	11.64	.721	.82	2.41	1.10	.63	2	2
5	1	30	4.80	.080	.520	.374	.225	1.42	6.74	.426	.93	.30	4.81	----	4	2
	2	70	4.09	.104	.461	.303	.187	1.46	3.75	.412	.92	.23	4.84	----	3	3
	3	160	3.94	.129	.442	.351	.278	1.86	5.00	.419	.89	.26	5.43	----	4	3
	Profile	----	4.14	.114	.462	.344	----	1.68	15.49	.418	.90	.26	5.16	.24	4	3
6	1	30	5.02	.064	.405	.325	.177	1.39	5.32	.379	.63	.25	0.61	----	3	2
	2	100	4.79	.082	.403	.349	.207	1.51	7.23	.544	.52	.83	0.61	----	3	2
	3	200	4.65	.078	.388	.307	.191	1.58	3.81	.587	.53	1.14	0.63	----	3	2
	Profile	----	4.75	.077	.396	.325	----	1.53	16.36	.541	.54	.90	0.62	.56	3	2
7	1	60	4.93	.055	.383	.261	.145	1.31	8.68	.501	.90	.58	0.54	----	3	2
	2	130	4.82	.054	.310	.235	.151	1.44	5.28	.693	.86	1.72	0.79	----	2	2
	3	270	4.37	.054	.266	.184	.133	1.54	3.74	1.013	.74	4.65	0.82	----	2	1
	4	280	4.17	.056	.270	.168	.121	1.50	.24	.898	.72	3.49	0.74	----	2	1
	Profile	----	4.60	.054	.302	.213	----	1.46	17.94	.819	.80	3.00	0.75	.69	2	2

$\overline{F}_p$ = Average moisture stress when sampled

$\overline{M}$ = Average moisture content when sampled

$\overline{SMC}$ = Average saturating moisture capacity

$\overline{AMC}$ = Average adsorbed moisture capacity

$\overline{\Delta M}$ = Moisture use between field capacity and ultimate plant stress as volume ratio

$\overline{\text{Vol. wt.}}$ = Average volume weight

M Use = Computed moisture depletion for horizon. Profile value is the sum of the horizon values

$\overline{EK}$ = Average erodibility constant

$\overline{TR}$ = Average transportability ratio

$\overline{IR}$ = Average minimum infiltration rate

$\overline{EC}$ = Electrical conductivity of saturated paste

Nat. cov. = Natural cover of live vegetation

RC = Revegetation textural classification
- 1 = Coarse soil - requires irrigation
- 2 = Marginal sandy loam soil
- 3 = Optimum soil texture
- 4 = Marginal clay loam soil
- 5 = Clay soils - require surface treatment

S.T. Req. = Surface treatment requirement such as Arcadia contour furrowing
- 1 = Probably no benefit
- 2 = Beneficial for erosion control
- 3 = Required for vegetation establishment

* Coal strata; excluded from profile averages

Table 17 Horizon and profile averages of the hydrologic data for the soils of the Otter Creek study area near Ashland, Montana (Continued)

Site	Horizon	Depth cm	$\overline{p^F}$	$\overline{M}$	$\overline{SMC}$	$\overline{AMC}$	$\overline{\Delta M}$ cc/cc	$\overline{Vol.}$ wt.	M use cm	$\overline{EK}$	$\overline{TR}$	$\overline{IR}$	$\overline{FC}$	Nat. cov.	RC	S.T. Req.
8	1	20	4.89	.073	.399	.333	.139	1.22	2.78	.503	.75	.58	0.71	----	3	2
	2	60	4.42	.075	.421	.258	.152	1.71	3.03	.378	.82	.16	0.83	----	3	2
	3	150	4.07	.084	.395	.242	.143	1.69	2.57	.368	.90	.18	3.39	----	2	3
	4	160	3.96	.072	.326	.197	.148	1.88	.30	.335	.85	.05	2.50	----	2	3
	Profile	----	4.25	.080	.398	.254	----	1.65	8.68	.385	.86	.22	2.36	.69	3	2
9	1	40	3.95	.065	.384	.170	.080	1.37	3.20	.574	.90	1.10	0.34	----	2	2
	2	90	2.19	.074	.224	.112	.073	1.63	1.83	1.089	.60	4.39	0.34	----	1	1
	3	130	2.94	.245	.620	.488	.229	1.36	2.29	.371	.92	.23	3.40	----	5	3
	4	160	3.32	.169	.632	.361	.238	1.92	1.43	.317	.94	.05	3.41	----	4	3
	Profile	----	3.03	.132	.439	.267	----	1.55	8.75	.636	.82	1.72	1.68	.91	3	2
10	1	30	4.66	.043	.304	.187	.122	1.45	3.65	.549	.91	.72	1.18	----	2	2
	2	60	4.20	.075	.343	.234	.204	1.94	3.06	.466	.94	.50	3.52	----	2	2
	3	110	3.90	.110	.531	.288	.210	1.80	2.10	.432	.84	.43	3.64	----	3	2
	4	130	3.92	.163	.660	.437	.328	1.92	1.31	.317	.61	.05	4.42	----	4	3
	Profile	----	4.15	.094	.455	.275	----	1.77	10.12	.449	.84	.46	3.17	.46	3	2
11	1	30	4.37	.058	.342	.206	.120	1.45	3.59	.481	.88	.46	0.50	----	2	2
	2	70	3.61	.072	.278	.171	.124	1.80	2.47	.436	.96	.24	1.58	----	2	2
	3	160	3.11	.110	.225	.220	.152	1.72	2.73	.495	.53	.44	2.10	----	2	2
	Profile	----	3.47	.091	.260	.205	----	1.69	8.79	.478	.71	.39	1.67	.55	2	2
12	1	30	4.29	.061	.358	.196	.091	1.17	2.74	.497	.72	.62	0.37	----	2	2
	2	90	3.88	.052	.296	.136	.104	1.91	3.11	.502	.89	.58	0.32	----	1	2
	3	120	3.62	.075	.295	.179	.168	2.13	1.01	.398	.94	.15	0.95	----	2	2
	Profile	----	3.92	.060	.311	.162	----	1.78	6.86	.475	.86	.48	0.49	.60	2	2

$\overline{p^F}$ = Average moisture stress when sampled

$\overline{M}$ = Average moisture content when sampled

$\overline{SMC}$ = Average saturating moisture capacity

$\overline{AMC}$ = Average adsorbed moisture capacity

$\overline{\Delta M}$ = Moisture use between field capacity and ultimate plant stress as volume ratio

$\overline{Vol.}$ wt. = Average volume weight

M Use = Computed moisture depletion for horizon. Profile value is the sum of the horizon values

$\overline{EK}$ = Average erodibility constant

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- 3 = Required for vegetation establishment

Table 17 (cont)

is saturated and not restrained so that it is free to swell, its theoretical maximum void ratio (TVR) would be the saturated moisture content times the density of soil particles (0.224)(2.65)=0.594 (Krynine 1947, p. 32). These void ratios are similar because this is a low-swell soil. The saturated void ratio (SVR) was also computed from the measured density of the saturated paste, as 0.838 but because saturation is never quite complete the two void ratios are not the same. The difference is a measure of the volume of air bubbles in the saturated paste. Conversions among void ratio, bulk density, total density, porosity, saturated moisture content by weight can be made using the nomograph (figure 7).

Inferences

On the basis of the data presented in table 17 some inferences and suggestions are made for the use of the surface soils for reclamation of the area if it is mined.

Soil profiles 1 and 7 have low moisture retention capabilities but infiltration rates are high. With frequent summer showers these soils are capable of sustaining good growths of grasses. They should be protected from erosion until vegetation is established.

Profiles 2 and 12 have low moisture retention capabilities and infiltration rates are low. Erodibilities are medium. The surface of these soils should be contour furrowed to retain all precipitation where it lands for use in establishing new vegetation. Profile 3 is shallow, with only 60 centimetres of soil overlying a coal strata. Retention capability of the soil is low, erodibility is high and infiltration rates decrease with depth. This soil is moderately saline.

Profiles 4 and 6 have medium moisture retention capabilities. Erodibilities and infiltration rates increase with depth in the profile. Mixing of the horizons may improve the soil characteristics.

Profiles 5 and 10 are saline soils with low infiltration rates and moderate erodibility and retention capabilities. These soils will require surface treatment such as contour furrowing to facilitate infiltration. Revegetation may not be successful without supplementary irrigation to leach the salts. However, contour furrowing without irrigation may cause sufficient leaching of the salts as has been demonstrated by Branson, Miller and McQueen (1966).

Profiles 8, 9, and 11 have low salinity at the surface and high salinity in the deeper horizons. Infiltration rates and erodibilities are not consistent. These soils should be contour furrowed to leach the salts downward because of the probably high salinity of a mixed profile.

▩ Pine savannah - prominent associated species include bluebunch wheatgrass and little bluestem

▥ Grassland and shrubland - has a variety of dominant species including needle-and-thread, western wheatgrass, prairie sandreed, and blue grama

▒ Breaks - steep and dissected lands with local areas dominated by greasewood, buckwheat, and green needlegrass

▤ Hay meadows - lowland irrigated areas with mixed introduced and native species

▦ Crested wheatgrass - a reseeded area in Section 2

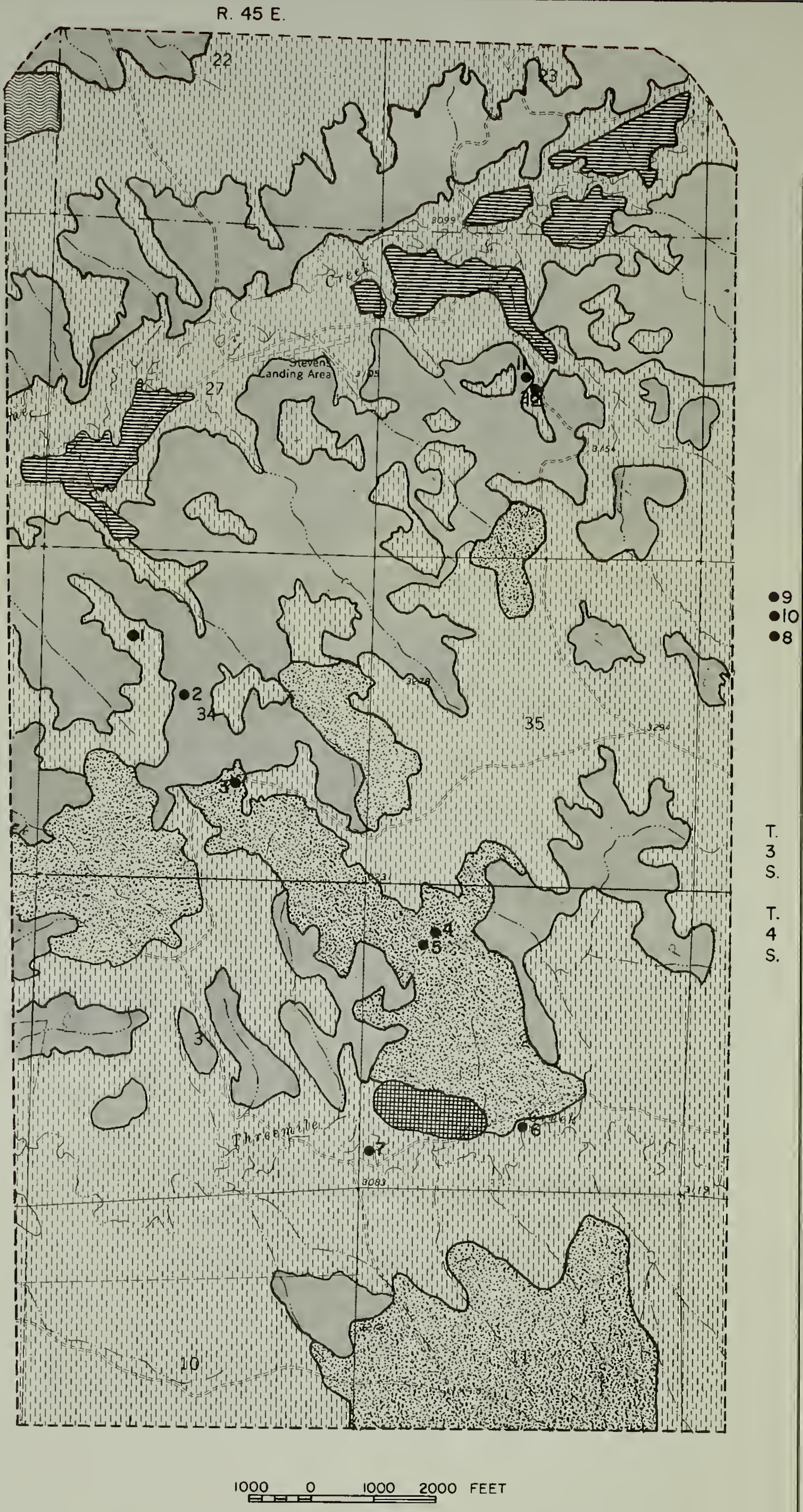
≋ Cultivated land - a small dryland crop area in Section 21

● 2 Locations of vegetation and soil sampling sites

Most of the species on this site are widely distributed members of the grassland formation of the northern Great Plains. Exceptions include ponderosa pine, which varies in cover from widely scattered trees to a near-forest stand of 30 percent, and greasewood, which represents an extention of the salt-desert shrub type characteristic of extensive areas in Utah and Nevada.

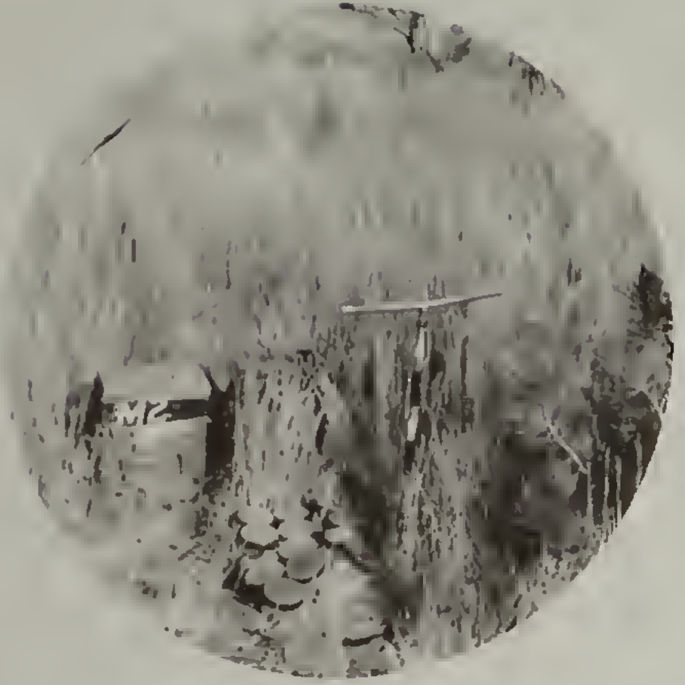
The ponderosa pine savannah is found on relatively coarse soils and is most abundant on steep, north-facing slopes. It is also common on relatively unweathered "scoria" or porcellanite.

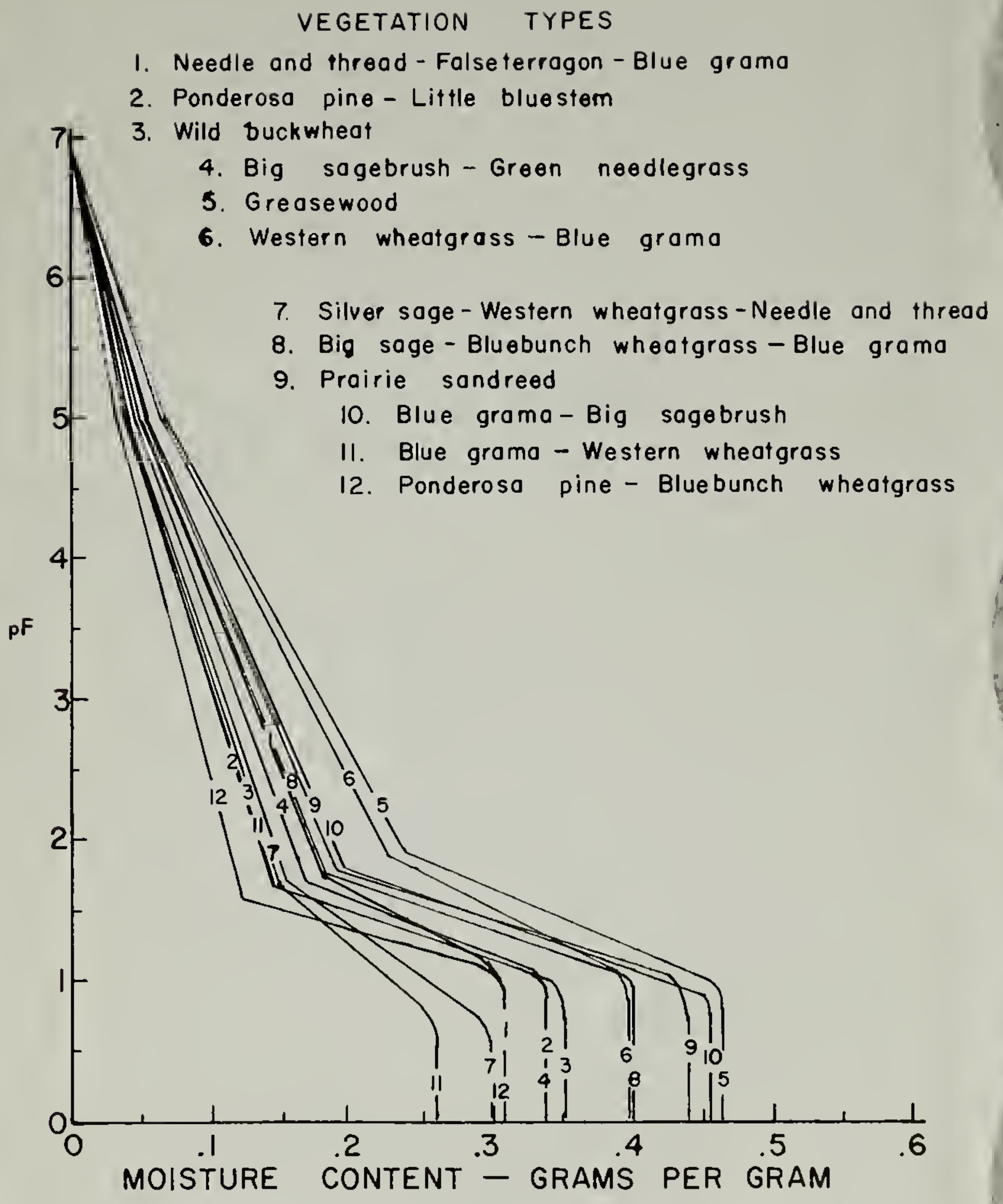
Grasslands and shrublands are most abundant on more developed soils on gently sloping uplands and on flood plains. Although grasses occupy most of the flood plains, woody species such as cottonwood, ash, box elder, chokecherry and silver sagebrush are abundant adjacent to permanent and some intermittent streams.



Vegetation of the Otter Creek Coal Field Study Site,
Powder River County, Montana, 1974

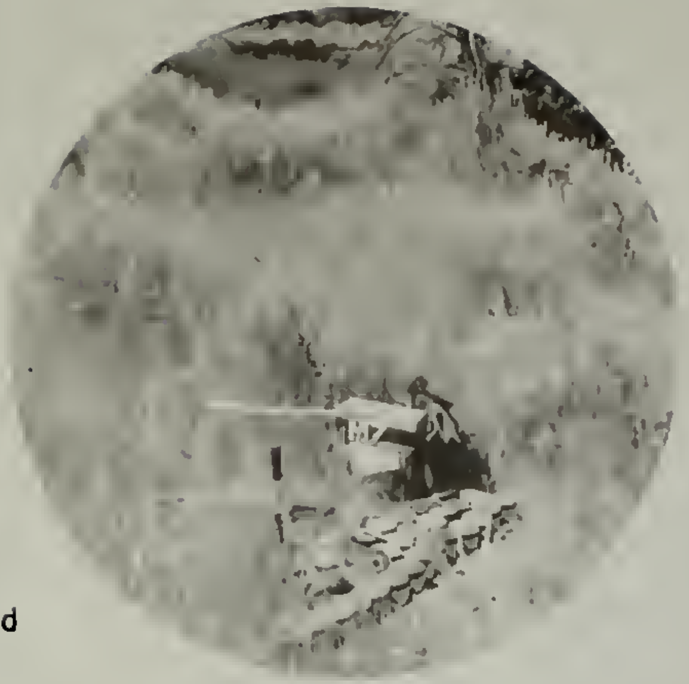
PLATE 38

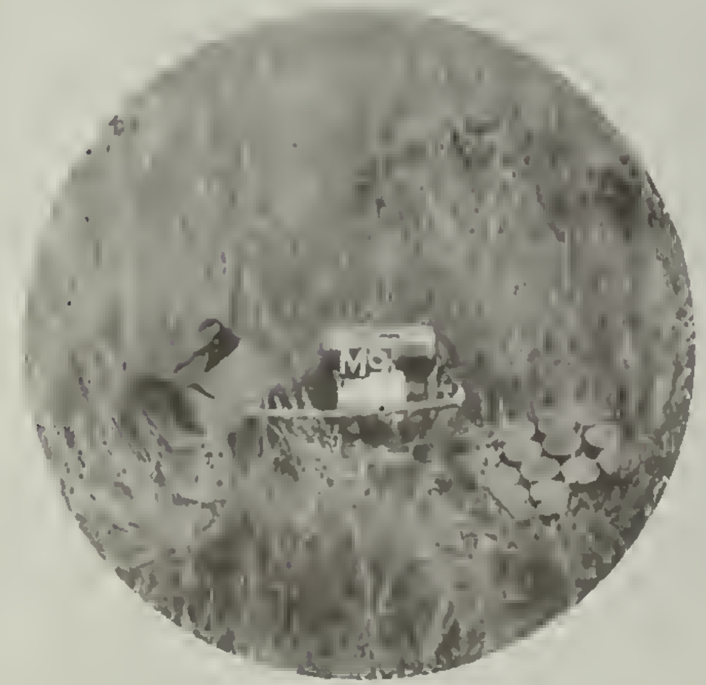




Locations of vegetation and soil-sampling sites, numbered on photos and curves, are shown on the vegetation map (Plate 38).

Soil Moisture Characteristics for Sampling Sites





SEDIMENT YIELDS

The sediment yield estimates presented in this section for the Otter Creek Coalfield study site were derived using a qualitative rating method. The estimates for some of the lower-yielding upland areas were verified by measurement of sediment deposition in four stock ponds. The sediment yields of the higher yielding areas are unverified, but are thought to be reasonably accurate.

Methods

The method used to obtain the source-area sediment yield estimates shown on plate was the (PSIAC) Pacific Southwest Interagency Committee (1968) method which entails the rating of nine factors: surface geology, soils, climate, runoff, topography, ground cover, land use, upland erosion, and channel erosion and sediment transport. While the method was developed to make broad sediment yield classifications for large areas, such as river sub-basins, Shown (1970) found that the method provides reasonable estimates for drainage areas as small as one-tenth of a square mile.

Source-area sediment yield estimates were actually made on 10 relatively homogeneous small watershed areas within the area shown in plate 40. Aerial photographs (1:15,000 scale) were then used to extend the estimates to the whole mapped area. Systematic interpretation of the photographs included consideration of (1) vegetation type (2) density of the vegetation, (3) landform type, (4) steepness and length of the slopes and (5) drainage density. Categories 2, 4, and 5 were rated on a relative basis within the mapped area on a scale ranging from 0 to 3, which corresponds to none, low, medium and high.

The basin sediment yields for drainage basins B, C, D, and F (plate 40), were computed by multiplying the area-weighted source-area sediment yield for each basin by a sediment delivery ratio. The sediment delivery ratio is the fraction of source-area sediment that is delivered at some downstream point in an integrated drainage network. A rating scheme developed by Frickel, Shown and Patton (1975), which utilizes point observations in the field and interpretation of aerial photographs, was used to obtain the sediment delivery ratios. The scheme considers the effects on sediment delivery by perennial and ephemeral streams, of various conditions such as (1) channel width and gradient, (2) whether the channel is gullied or just a broad, grassy drainageway, (3) the size of the bed material and vegetative cover on the bed, (4) intermittent gullies in the channel system and (5) evidence of deposition in the channels and the occurrence of alluvial fans and deposition on bottomlands where flows spread either naturally or because of man-made impoundments or diversions of water.

Sediment deposition was measured in four stock ponds on and near the site (see plate 40 for locations). The ages of these ponds were obtained from local ranchers, and it was ascertained that these ponds usually did not spill excessively. Three of the ponds were dry in

August 1974 at which time the thickness of sediment in them was determined by boring with a hand auger at several locations in each pond. The base of the sediment was picked where the texture of the material changed from grayish silty clay loam to a yellowish sandy clay containing sandstone and clinker fragments. The latter material was usually similar to the soils of the adjacent terraces and was assumed to be the material on the original bottoms of the ponds. One pond had water in it so the sediment was probed with a 1/2-inch rod while wading. The depth at which the resistance to probing increased markedly was taken as the base of the sediment deposit. The depth of water was determined by sounding. The probe method was checked near the upper end of the pond by augering and probing adjacent spots.

Amounts of bare soil were obtained while making vegetation measurements along 50-foot transects at selected sites on the study area. The measurements were extrapolated to other parts of the study area using aerial photographs.

Slope gradient categories were delineated on 1:24,000 scale topographic maps, and several measurements of gradient were made in each slope category.

Channel cross-sections monumented with steel pins at the ends were installed and surveyed at locations A, C, D, and E shown on plate 40. If upstream areas are mined in the future, these cross-sections could be resurveyed periodically to determine the effect of mining and rehabilitation on channel erosion or deposition.

Results

Source-area sediment yields

Source-area sediment yields are generally low for much of the study area as is shown on plate 40. There are several reasons why this is true: (1) amounts of bare soil are low because of the excellent cover of vegetation and mulch, and some rocks in the 0-.2, .1-.3 and .2-.4 acre-feet per square mile categories; (2) the soils on the uplands in these sediment yield categories are coarse-textured and rather permeable owing to their sandstone and clinker parent materials; and (3) the topography is flat to gently sloping for most of this area of low sediment production.

Above about 0.4 acre-feet per square mile the sediment yields increase as the amount of bare soil increases, with apparently a smaller effect due to increased slope gradients (see explanation table on plate 40). The drainage density increases markedly for the areas yielding more than about 0.4 acre-feet per square mile. That is indicative of increased runoff and erosion owing to finer-textured soils because of more shale influence than in the lower sediment yielding areas.

Basin sediment yields

The sediment yields for the basins that had stock ponds at their outlets are shown in table 18.

Table 18. --Sediment yields obtained by surveying stock ponds on the Otter Creek Coal Field Study Site

Pond	Age (years)	Drainage area (mi^2)	Annual sediment yield (acre-ft/mi^2)	Average watershed slope (percent)	Estimated bare soil[2] (percent)	Drainage density[3] (mi/mi^2)
P1	14	.21	.33	12	5	6.4
P2	about 40	.79	.21	11	11	7.9
P3[1]	about 40	.23	.20	13	3	3.1
P4	13	.45	.36	12	17	13.6

[1] Located about one-half mile east of study site in SE-1/4 sec. 25, T. 3 S., R. 45 E.

[2] Based on measurements of bare soil on the study site that were extrapolated to these basins using aerial photographs.

[3] The density in miles per square mile of drainage area of channels larger than third order as discernible on 1:15,000 scale aerial photographs.

The values are probably indicative of accurate values for the sediment yield, but they should not be considered absolute because the spudding method used to obtain the values is not error free. There are no marked differences among the sediment yields of the four basins; however, as shown in table 18 the yields to ponds 1, 3, and 4 relate to the amount of bare soil and drainage density. Basin 2 has about the same sediment yield as basin 3 and a smaller yield than basin 1 even though the amount of bare soil and drainage density are the largest for the three basins. This may be caused by the larger drainage area for basin 2 which presents more opportunity for sediment to be deposited on bottomlands and in channels, thus resulting in a lower sediment delivery ratio. Hadley and Schumm (1961) demonstrated in the Cheyenne basin of Wyoming that sediment yields per unit of area decrease markedly for drainage areas between 0.03 and 1.5 square mile.

Estimated basin sediment yields for four additional drainage basins and the channel characteristics at their arbitrarily chosen outlets are shown in table 19.

There are many indications that the present rate of channel erosion on the study area is very small. Most of the tributary channels on the study site have vegetated beds and banks as only a few channels are designated as raw and gullied (see plate 40). There are some low headcuts present in some channels but their advance appears to be slow. In certain reaches of Home and Threemile Creeks on the study area the channel beds are unvegetated but the only minor erosion is occurring at the occasional cutbanks and low headcuts.

Many of the channels on the site appear to be slowly filling up with sediment. A chief indication of this is the fact that the size of the

Table 19--Basin sediment yields and channel characteristics for the Otter Creek Coal Field Study site

Basin[1]	Drainage area (mi^2)	Weighted source-area sediment yield (acre-ft/mi^2)	Sediment delivery factor	Estimated annual basin sediment yield (acre-ft/mi^2)	Channel characteristics at basin outlets				Gradient (percent)
					Form	Bed and bank material and cover	Geometry[3] width(ft)	mean depth(ft)	
A[2]	52.8	--	--	--	deeply incised, steep banks, long pools, short riffles	silt; grasses, forbs, shrubs, trees	10.2	.46	.5
B	.27 (uncontrolled area below stock pond)	.21	.5	.1	shallow, well vegetated	silt, small clinker fragments; grasses and shrubs	3.0	.35	.75
C	.54	.33	.65	.2	moderately incised, well vegetated	silt, sandstone and clinker fragments; grasses and shrubs	5.6	.37	.5
D	.45	.39	.75	.3	relatively wide, well vegetated	grasses and shrubs	7.1	.57	.6
E[2]	49.4	--	--	--	deeply incised, moderately vegetated	fine sandy loam; forbs, grasses, shrubs and trees	4.2	.33	.35
F	1.01	.57	.5	.3	deeply incised, well vegetated	grasses and shrubs	3.0 little evidence of flow	.4	2.

[1] Locations of the arbitrarily chosen outlets of the basins are shown on the sediment yield map (Plate 40).

[2] Sediment yield estimate was not made because the amount of controlled drainage area is unknown.

[3] The geometry is for the lower part of the channel which is actively involved in the transportation of water and sediment during usual, non-extreme flows.

sediment particles on most channel beds is the same size as the particles that makeup the alluvium in the channel banks. It could be argued that the bed material results from bank erosion, which may be true, in part. However, in channels that are either degrading or stable the bed material is usually coarser than the bank material. Another indication of channel filling was observed in vegetated reaches along both Home and Threemile Creeks and some tributaries where the bases of trees in or near the channel bed were buried with up to 2 feet of stable sediment.

At the present time it appears that much of the sediment load of many of the main tributaries does not reach Home or Threemile Creeks. In some places, particularly along Home Creek, the water is diverted onto the bottomland terraces to irrigate hayland and cropland where most of the sediment load probably is deposited. In other places, the flows in untrenched channels spread naturally across the well-vegetated bottomlands and much sediment is dropped from these shallow flows.

Effects of mining

The large estimates for sediment yields from ungraded and graded but barren overburden areas shown in table 20 emphasize the necessity

Table 20. --Estimates made with the PSIAC method of annual sediment yield from presumed disturbed overburden areas before, during, and after reclamation for the Otter Creek Coalfield Study Site

	Ungraded overburden banks	Graded overburden[1]	Overburden during reclamation period[2]	Overburden after the soils and perennial vegetation have stabilized[4]
Average slope (percent)	75-100	10-12	10-12	10-12
Estimated bare soil (percent)	90(rock,10)	90(rock,10)	40-50	5-10
Estimated annual sediment yield (acre-ft/mi^2)	3-5	.5-1.5	.2-.6[3]	.1-.3

---

[1] Assumed that the graded overburden would be covered with available soil. For areas where soil will not be available, it was assumed that the overburden would be contour furrowed or pitted to increase soil moisture and reduce erosion.

[2] Assumed that adapted native species would be seeded along with a temporary cover crop and that no irrigation water would be applied. It was further assumed that the area would not be grazed during this 5- to 10-year reclamation period.

3/ This range of values indicates changes over time during the period as well as differences over the area because of different gradients and lengths of slopes and amounts of cover.

4/ Assumed that the area would be moderately grazed at that time.

for establishing vegetative cover on them as soon as possible if the study area is mined. Sediment yields from the overburden areas during the reclamation period, when the permanent vegetation and soil structure is becoming established, will be greater than the present rates from those areas shown on plate 40 yielding less than 0.4 acre-feet per square mile. For instance, the indicated average sediment yield near the beginning of the reclamation period would be, at least, 0.4 acre-feet per square mile which is a larger rate than estimated for present (1974) conditions on much of the upland area of the study site (see plate 40).

Even during the reclamation period, and most certainly thereafter, the estimated sediment yields from the overburden areas are less than for those areas presently yielding more than 0.6 acre-feet per square mile. This should occur because slopes will be less steep, and most likely, the vegetative cover will be much denser because the weathered shales that now exist in some places can likely be modified with some clinker fragments or sandy material and topped with a thin layer of alluvium from the tributary valleys. Also, mechanical treatments such as contour furrowing (Branson, Miller and McQueen, 1966) or gouger pitting (Sindelar, Hodder and Majerus, 1973) would increase soil moisture and reduce runoff and erosion.

Some means will be necessary to control the sediment from the overburden areas during mining and reclamation. This could be accomplished by reservoirs immediately downstream from the mined area, and from which the water would be discharged in nonerosive quantities. The reservoirs may need to be cleaned out periodically to maintain storage capacity and it may be desirable, for a number of reasons, to destroy the dam and spread the dam material and sediment at the end of the rehabilitation period.

Increased sediment yields may occur from the area downstream from a mine if water from the mine or a reservoir is discharged more-or-less continuously into channels that were formerly dry most of the time. These discharges probably would be small and thus nonerosive, however they would saturate the bed and banks of the channels. Then during a natural flood event severe erosion could occur, particularly in presently ungullied channels, because saturated alluvium is much more erodible than dry alluvium. A possible solution would be to pipe the water down to Otter Creek which is the surface and ground waters' ultimate destination with or without mining.

If the area is mined, sediment yield would be minimized if the reconstructed terrain includes rather wide valleys. Then, if the valleys trench, hillslopes would be intercepted only at places where the stream meanders to the valley sides. Thus hillslope areas from which material might slough, creep or slump into the channels would be minimized.

SOURCE-AREA SEDIMENT YIELDS AND CHANNEL CONDITIONS
ON THE OTTER CREEK COAL FIELD STUDY SITE

EXPLANATION

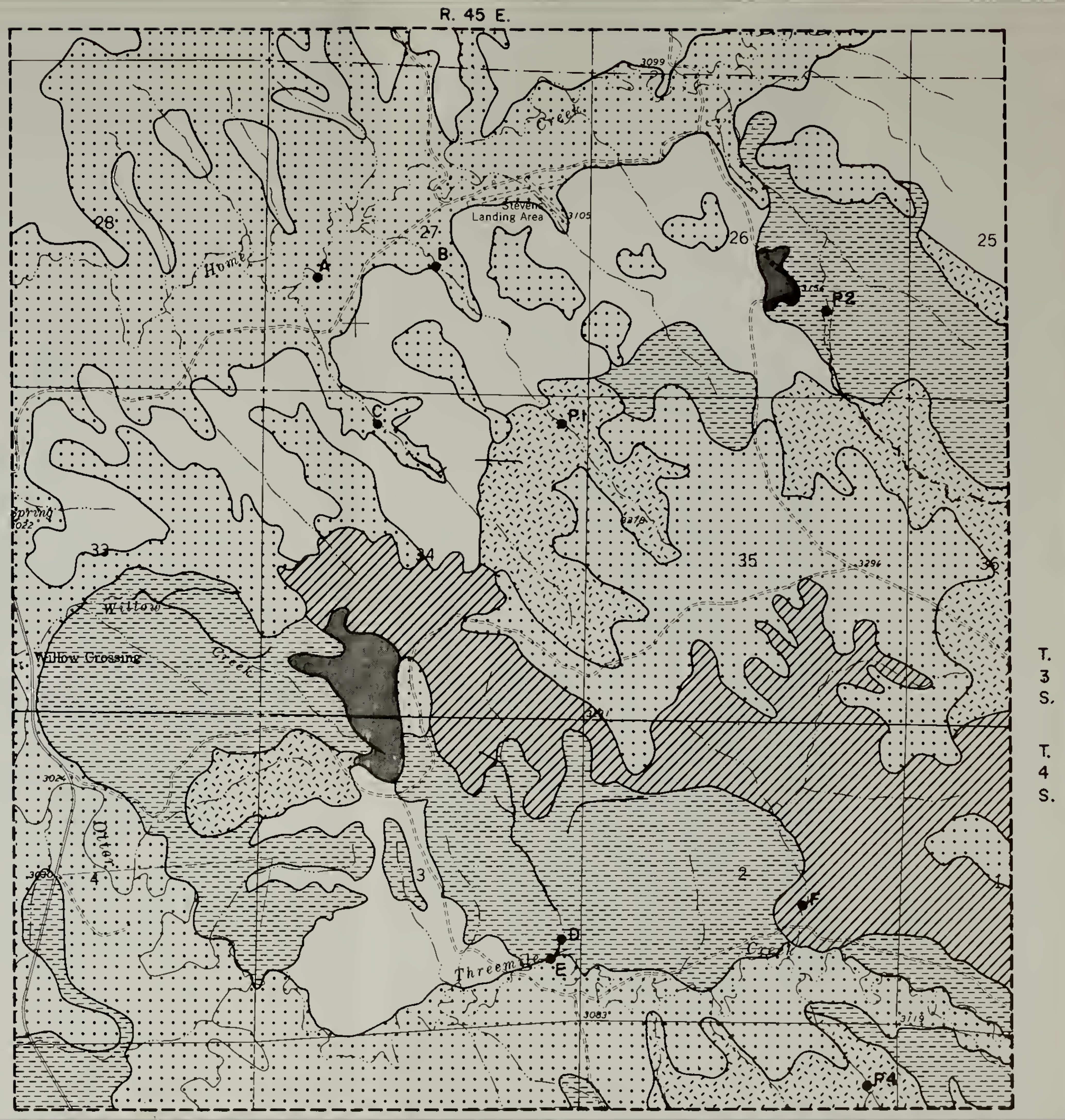
Annual source-area sediment yield (acre-ft/mi^2)	Topography	Relative drainage density	Slope gradients (percent)		Bare soil (percent)	Surficial geology
			range	mean		
░ 0-.2	a) bottomlands	low	0-1	1	0-2.5	alluvium
	b) gentle hillslopes	very low	6-9	8	0-2.5	clinker
	c) tablelands	very low	2-8	4	0-2.5	sandstone and clinker
☐ .1-.3	hillslopes (pine savannah)	low	9-33	22	1.0-19.8	clinker and sandstone
▤ .2-.4	hillslopes	low to moderate	18-25	21	0-25.5	clinker, sandstone, shale
▒ .4-.6	hillslopes	moderate	14-53	20	2.5-66.2	sandstone and shale
▨ .6-.8	hillslopes	high	12-33	20	11-66.2	sandstone and shale
■ .8-1.2	hillslopes	high (rill density)	15	15	50E-66.2 (E=estimated)	shale

● A Locations of arbitrarily chosen outlets of basins for which sediment yield estimates were made.

● P1 Locations of stock ponds that were surveyed to obtain basin sediment yields.

∼ Raw gullied channels

- ∼ - Intermittently gullied channel



Base from U.S. Geological Survey
Willow Crossing 7½-minute quadrangle

HYDROLOGIC STUDY

Introduction

Data on the subsurface and surface waters in the Otter Creek Study Area were collected during the winter of 1974 and spring of 1975. These data, both quantative and qualitative, were collected from existing wells in the area, holes bored for overburden analysis in the study area in 1974, and streamflow records collected since October 1972.

Adequate reclamation of the Otter Creek Study Site subsequent to strip mining would be possible without irrigation of the spoils. Recently developed techniques of top soiling, mulching, and surface manipulation can limit surface runoff and maximize utilization of precipitation (Sindelar and others, 1973). Adequate description of surface and groundwater necessitates some discussion of the potential use of water for irrigation. Therefore, some of the following discussions relate chemical quality to irrigation.

The ground and surface-water supplies at the study site are small. The quality of the streamflow and groundwater may not be suitable for irrigation unless special precautions are taken. Should supplemental water be required, additional studies should be made of plant-soil-water relationships on reconstructed surface material. The water pumped from wells in the area is used for domestic and stock purposes. Although, most samples tested exceeded the recommended chemical standards set forth by the U.S. Public Health Service for drinking water used on interstate carriers.

Streams

Data to describe the quantity and quality of stream flow near the Otter Creek coalfield has been collected since October 1972. Although long-term records are not available, data from recently installed gaging and sampling stations indicate that except for spring runoff, surface water is small in quantity and of poor chemical quality.

Quantity

Otter Creek, about 1 mile west of the Otter Creek field, is the only perennial stream in the vicinity. Daily discharges of Otter Creek at Ashland are presented on table 21. The gaging station is six miles downstream (north) from the coal field. The mean annual flood for Otter Creek at Ashland estimated from its drainage area using the procedure outlined by Patterson (1966) is 2,100 cfs (cubic feet per second). The discharge of the 25-year flood is about 9,000 cfs.

Home and Threemile Creeks, both intermittant tributaries to Otter Creek, are the north and south boundaries of the coalfield, respectively. The intermittant East Fork of Otter Creek is the only stream to join the main stem of Otter Creek between Home Creek and Otter Creek

Table 21.--Daily discharge for Otter Creek at Ashland, Montana, October 1, 1972 through September 30, 1974

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1972 TO SEPTEMBER 1973

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	3.8	4.6	5.7	3.0	7.0	18	5.0	14	6.3	4.0	1.4	.96
2	4.3	5.2	5.0	3.0	7.0	19	4.8	14	7.0	4.8	1.4	1.0
3	4.3	5.4	3.5	2.5	7.0	19	4.8	11	7.4	4.0	1.7	1.6
4	4.0	5.4	2.0	2.5	7.0	18	4.6	12	6.5	3.5	1.5	2.0
5	4.0	5.4	1.0	2.5	7.0	17	4.5	12	6.1	3.0	1.3	4.1
6	4.0	6.1	1.0	2.5	6.0	15	4.6	11	5.9	2.8	1.4	2.6
7	4.0	5.2	1.0	2.0	5.0	15	4.6	10	5.9	2.7	1.5	1.9
8	4.1	5.2	1.5	1.5	5.5	14	4.8	9.8	6.1	2.6	1.4	1.7
9	4.0	5.2	1.5	1.0	6.0	13	5.7	8.8	5.9	2.7	1.4	1.7
10	4.0	5.4	1.5	1.5	7.0	11	6.7	8.3	5.5	2.5	1.4	2.2
11	4.5	5.2	2.0	2.5	7.0	11	7.0	7.6	5.0	2.2	1.4	2.0
12	4.5	5.2	2.5	5.0	6.5	12	7.0	7.4	4.8	2.0	1.4	2.0
13	4.5	5.4	2.5	6.0	6.0	10	6.7	7.0	4.6	1.9	1.4	2.0
14	4.5	5.2	3.0	7.0	6.5	13	6.7	6.7	4.6	1.8	1.2	2.0
15	4.5	5.4	3.5	8.0	7.5	10	6.7	6.5	4.5	1.7	1.1	2.0
16	4.3	5.4	4.0	7.0	7.0	8.5	6.5	6.5	4.3	1.6	1.1	2.0
17	4.3	5.4	4.0	6.0	6.5	7.2	6.3	6.3	4.1	1.5	1.1	2.0
18	4.3	5.4	4.0	4.0	6.0	6.3	6.7	6.1	4.1	1.4	1.0	2.0
19	4.5	5.0	4.0	3.5	5.5	5.9	9.3	6.1	4.5	1.4	.80	2.0
20	4.6	4.8	4.0	3.0	5.0	5.7	14	5.9	4.8	1.5	1.0	2.0
21	4.8	6.1	4.0	3.0	5.0	5.5	13	5.5	4.5	1.5	1.0	1.5
22	4.8	8.5	4.0	3.0	7.0	5.4	14	5.2	4.3	1.6	1.1	1.5
23	4.8	6.3	4.0	3.0	10	5.9	17	5.2	4.3	1.5	1.1	1.5
24	5.2	5.4	4.0	4.0	25	5.9	16	5.2	4.8	2.3	1.0	1.5
25	5.2	5.4	4.0	5.0	45	5.7	14	5.5	4.6	2.6	.88	1.5
26	5.2	5.5	4.0	5.0	37	5.5	13	6.7	4.5	2.0	.96	1.5
27	5.2	5.6	4.0	4.0	22	5.4	14	7.2	4.1	1.7	1.0	1.5
28	4.8	5.4	4.0	5.0	20	5.5	12	6.5	3.8	1.7	1.0	1.5
29	4.5	5.5	3.5	6.0	------	5.4	10	6.1	3.7	1.5	.96	1.5
30	4.1	5.5	3.5	6.5	------	5.4	12	6.1	3.5	1.4	.96	1.5
31	3.7	------	3.0	7.0	------	5.2	------	6.1	------	1.5	.88	------
TOTAL	137.3	164.5	99.2	125.5	299.0	309.4	262.0	242.3	150.0	68.9	36.74	54.76
MEAN	4.43	5.48	3.20	4.05	10.7	9.98	8.73	7.82	5.00	2.22	1.19	1.83
MAX	5.2	8.5	5.7	8.0	45	19	17	14	7.4	4.8	1.7	4.1
MIN	3.7	4.6	1.0	1.0	5.0	5.2	4.5	5.2	3.5	1.4	.80	.96
AC-FT	272	326	197	249	593	614	520	481	298	137	73	109

WTR YR 1973 TOTAL 1,949.60 MEAN 5.34 MAX 45 MIN .80 AC-FT 3,870

Table 21 (Cont.)

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1973 TO SEPTEMBER 1974

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	1.6	3.1	4.0	3.0	12	16	7.9	5.5	8.1	1.1	.53	.40
2	1.6	3.1	3.9	3.0	9.0	20	7.8	5.5	6.6	.97	.49	.46
3	1.6	3.1	4.0	3.0	8.0	14	7.5	5.4	5.8	2.4	.46	.40
4	1.6	3.0	4.3	3.0	7.5	10	7.5	5.2	5.5	7.4	.45	.35
5	1.7	3.0	4.3	3.0	7.5	11	7.6	5.1	5.4	9.1	.43	.35
6	1.8	3.0	4.3	3.0	7.0	11	7.3	5.0	5.4	3.4	.44	.30
7	2.3	3.0	4.3	3.1	7.0	7.4	8.1	4.7	5.4	2.5	.50	.25
8	1.7	3.0	4.3	3.2	7.0	7.3	8.4	4.8	6.1	1.9	.46	.25
9	1.7	3.1	4.2	3.2	8.0	7.1	8.2	4.3	5.9	1.7	.47	.25
10	1.8	3.4	4.1	3.2	60	7.3	8.1	3.3	5.4	1.9	.50	.25
11	1.9	3.3	4.1	3.3	100	7.7	9.0	4.5	5.0	1.9	.52	.20
12	2.1	3.3	4.0	3.3	110	7.2	8.8	4.7	4.6	1.7	.52	.25
13	4.2	3.4	3.9	3.4	90	4.6	8.7	4.7	4.3	1.7	.52	.30
14	2.9	3.4	3.8	3.5	80	7.1	8.0	4.9	4.3	1.4	.52	.30
15	2.6	3.4	3.7	3.8	70	6.1	7.7	4.9	4.2	1.3	.52	.30
16	2.5	3.4	3.6	4.0	65	6.4	7.3	4.8	3.7	1.1	.46	.30
17	2.5	3.7	3.5	5.0	60	6.5	7.0	4.8	3.6	1.1	.46	.25
18	2.5	3.7	3.2	10	55	8.4	6.7	5.0	3.1	1.1	.46	.20
19	2.5	3.7	2.7	20	45	7.6	6.3	5.3	2.9	.93	.46	.20
20	2.5	3.4	2.9	60	30	6.5	6.1	6.4	2.5	.81	.40	.20
21	2.5	3.4	3.0	120	23	7.8	5.9	6.7	2.5	.76	.40	.16
22	2.5	3.6	3.2	100	20	7.3	5.9	6.3	2.3	.73	.40	.16
23	2.6	3.7	3.3	70	18	6.9	5.9	5.9	2.3	.67	.40	.20
24	2.6	3.6	3.4	60	16	7.4	5.7	5.7	2.0	.52	.35	.20
25	2.6	3.6	3.4	55	15	8.5	5.6	7.0	1.8	.52	.35	.20
26	2.6	3.9	3.4	50	16	7.6	5.5	6.5	1.6	.48	.35	.20
27	2.7	3.9	3.4	45	17	7.8	5.6	5.7	1.4	.49	.35	.20
28	2.7	4.0	3.4	40	14	8.3	5.8	6.3	1.2	.46	.30	.20
29	2.7	3.4	3.3	35	------	8.2	5.8	6.1	1.2	.50	.30	.20
30	2.7	3.7	3.1	20	------	8.0	5.7	6.3	1.1	.55	.35	.20
31	2.9	------	3.0	15	------	7.9	------	8.7	------	.50	.35	------
TOTAL	72.7	102.3	113.0	757.0	977.0	264.9	211.4	170.0	115.2	51.59	13.47	7.68
MEAN	2.35	3.41	3.65	24.4	34.9	8.55	7.05	5.48	3.84	1.66	.43	.26
MAX	4.2	4.0	4.3	120	110	20	9.0	8.7	8.1	9.1	.53	.46
MIN	1.6	3.0	2.7	3.0	7.0	4.6	5.5	3.3	1.1	.46	.30	.16
AC-FT	144	203	224	1,500	1,940	525	419	337	228	102	27	15

CAL YR 1973 TOTAL 1,936.60 MEAN 5.03 MAX 45 MIN 1.6 AC-FT 3,840
WTR YR 1974 TOTAL 2,856.24 MEAN 7.83 MAX 120 MIN .15 AC-FT 5,670

at the Ashland gaging station. To date, no gages have been placed on these tributaries, which flow only during spring runoff and in response to heavy rainfall. Home Creek and Threemile Creeks have about the same size drainage areas, 58.8 and 51.5 square miles, respectively, and should have generally the same flow characteristics. During a period of snowmelt on January 20, 1975, Threemile Creek was discharging 1.8 cfs; on March 19, 1975, about 20 cfs (table 22 and 23).

Floods with a two-year return interval were estimated for Home and Threemile Creeks from their respective channel geometries using relationships developed from measured streams in the region. The two-year flood on Home Creek is about 45.1 cfs; the two-year flood for Threemile Creek is 14.2 cfs. The discharge of the 25-year flood is estimated to be 671 and 235 cfs for Home and Threemile Creeks, respectively.

Ground Water

The Otter Creek coalfield is underlain by water-bearing zones of two distinct characters: (1) an unconfined or water-table aquifer; and (2) a series of confined deep aquifers. The unconfined aquifer is composed of lenticular, semiconsolidated to well-indurated clay, silt, sand, and coal in the Tongue River Member of the Fort Union Formation; clay, silt, and sand in the alluvium; and baked rocks in the clinker. The saturated thickness may be as much as 420 feet at the eastern edge of the field. The Knoblock coal is the most continuous bed in the water-table aquifer. The water-table aquifer is separated from the confined aquifers by 150-160 feet of soft clay shale, the Lebo Shale Member of the Fort Union Formation (Bass, 1932). The confined deep aquifers for which a modicum of information is available are the Tullock Member of the Fort Union Formation, the Hell Creek aquifer, basal Hell Creek-Fox Hills aquifer, Judith River Formation, Eagle Sandstone, Muddy Sandstone Member of the Thermopolis Shale, and the Madison Group.

System for Describing Geographic Locations

All well and chemical sampling locations in this report are specified by U.S. Bureau of Reclamation drill hole numbers for U.S.B.R. holes and location codes derived from the General Land Office system of land subdivision. The codes may consist of as many as 12 characters. The first two characters specify the township; the next three, the range. The next two characters specify the section number within the township. The next four letters specify the location within the quarter section (160-acre tract), the quarter-quarter section (40-acre tract), the quarter-quarter-quarter section (10-acre tract), and the quarter-quarter-quarter-quarter section (2-1/2-acre tract). Subdivisions of a section are designated A, B, C, and D in a counterclockwise direction, beginning in the northeast quadrant. If there is more than one feature in a 2-1/2-acre tract, consecutive digits beginning with 2 are added to the location number. For example, a well numbered 3S45E27ACBC would be a well inventoried in the SW 1/4 of the NW 1/4 of the SW 1/4 of the NE 1/4 of section 27, Township 3 South, Range 45 East (figure 9).

Table 22. --Representative chemical Analyses of Surface Water in the vicinity of the Otter Creek Study Site.

LOCATION	DATE	DIS-CHARGE (CFS)	DIS-SOLVED CAL-CIUM (CA) (MG/L)	DIS-SOLVED MAGNE-SIUM (MG) (MG/L)	DIS-SOLVED SODIUM (NA) (MG/L)	DIS-SOLVED POTAS-SIUM (K) (MG/L)	BICAR-BONATE (HCO3) (MG/L)	CAR-BONATE (CO3) (MG/L)	DIS-SOLVED SUL-FATE (SO4) (MG/L)	DIS-SOLVED CHLO-RIDE (CL) (MG/L)	DIS-SOLVED SOLIDS (SUM OF CONSTI-TUENTS) (MG/L)
Otter Creek at Ashland	74-10-02	0.22	67	150	390	24	660	3	1100	12	2080
DO	74-11-21	3.0	77	180	440	27	660	0	1200	16	2270
DO	74-12-19	3.0	110	180	420	18	750	0	1200	14	2320
DO	75-01-10	2.6	120	160	460	20	810	0	1500	14	2690
DO	75-01-22[a]	131	23	15	30	8.5	110	0	100	3.2	240
DO	75-02-06	6.2	83	95	220	16	440	0	690	8.8	1350
Otter Creek at Otter Creek Road [1]	74-07-13	--	34	210	440	20	470	6	1400	15	2400
DO	74-07-15	--	33	210	450	20	450	14	1400	18	2440
DO	74-07-16	--	34	210	460	20	460	12	1400	15	2470
Threemile Creek near Ashland [2]	75-01-20[a]	1.8	17	8.2	18	8.4	80	0	49	2.0	149

[1] NE¼,NW¼, Section 4, Township 4 South, Range 45 East.

[2] NW¼,SE¼, Section 3, Township 4 South, Range 45 East

[a] Analysis represents snowmelt over frozen ground.

Table 23 --Chemical and spectrographic analyses of water samples collected from Threemile Creek near Ashland and Otter Creek at Ashland.

DATE	TIME	TEMPER-ATURE (DEG C)	AIR TEMPER-ATURE (DEG C)	INSTAN-TANEOUS DIS-CHARGE (CFS)	TUR-BID-ITY (JTU)	SPE-CIFIC CON-DUCT-ANCE (MICRO-MHOS)	DIS-SOLVED OXYGEN (MG/L)	PER-CENT SATUR-ATION	BIO-CHEM-ICAL OXYGEN DEMAND 5 DAY (MG/L)	PH (UNITS)	CARBON DIOXIDE (CO2) (MG/L)	ALKA-LINITY AS CACO3 (MG/L)
06307730 - THREEMILE CREEK NEAR ASHLAND, MT. (LAT 45 30 46 LONG 106 09 25)												
JAN., 1975												
20...	0930	.0	1.0	1.8	20	260	11.2	85	10	7.5	4.0	66
MAR.												
19...	1245	3.5	20 --	20	100	355	10.6	89	10 --	7.6	3.8	78
06307740 - OTTER CREEK NEAR ASHLAND, MT. (LAT 45 35 18 LONG 106 15 17)												
OCT., 1974												
02...	1000	5.0	8.0	.22	10	2980	7.4	64	2.5	8.6	2.7	550
NOV.												
21...	1230	2.0	14.0	3.0	50	3230	12.0	97	1.9	8.5	3.3	539
DEC.												
19...	1230	.0	2.5	2.9	8	3900	11.9	90	1.4	8.2	7.6	614
JAN., 1975												
10...	0845	.0	-19.0	2.5	8	3500	10.8	82	1.8	8.0	13	664
22...	0915	.0	-3.0	131	70	410	11.8	90	9.3	8.2	1.1	90
FEB.												
06...	1030	.0	-13.0	6.2	30	1800	10.6	81	4.5	7.7	14	362
MAR.												
06...	1230	.0	10 --	260	100	370	11.0	84	4.0 --	7.2	12	98

Table 23 (cont)

DATE	BICAR-BONATE (HCO3) (MG/L)	CAR-BONATE (CO3) (MG/L)	TOTAL NITRO-GEN (N) (MG/L)	ORGANIC NITRO-GEN (N) (MG/L)	AMMONIA NITRO-GEN (N) (MG/L)	TOTAL KJEL-DAHL NITRO-GEN (N) (MG/L)	TOTAL NITRITE PLUS NITRATE (N) (MG/L)	TOTAL PHOS-PHORUS (P) (MG/L)	TOTAL ORGANIC CARBON (C) (MG/L)	HARD-NESS (CA,MG) (MG/L)	NON-CAR-BONATE HARD-NESS (MG/L)	DIS-SOLVED CAL-CIUM (CA) (MG/L)
06307730 - THREEMILE CREEK NEAR ASHLAND, MT. (LAT 45 30 46 LONG 106 09 25)												
JAN., 1975 20...	90	0	1.3	1.3	.01	1.3	.04	.16	43	76	11	17
MAR. 13...	95	0	1.2	1.0	.09	1.1	.06	.36	--	96	18	22
06307740 - OTTER CREEK NEAR ASHLAND, MT. (LAT 45 35 18 LONG 106 15 17)												
OCT., 1974 02...	665	3	1.0	.75	.20	.95	.06	.03	--	780	230	67
NOV. 21...	657	0	1.2	.91	.09	1.0	.23	.11	--	930	390	77
DEC. 19...	749	0	.88	.38	.11	.49	.34	.04	--	1000	400	110
JAN., 1975 10...	810	0	1.4	.65	.14	.79	.60	.02	--	960	290	120
22...	110	0	1.9	1.6	.11	1.7	.14	.17	--	120	29	23
FEB. 06...	441	0	1.8	1.2	.14	1.3	.51	.09	--	600	240	83
MAR. 06...	120	0	2.1	1.6	.28	1.9	.16	.68	--	130	29	23

DATE	DIS-SOLVED MAG-NE-SIUM (MG) (MG/L)	DIS-SOLVED SODIUM (NA) (MG/L)	SODIUM AD-SORP-TION RATIO	PERCENT SODIUM	DIS-SOLVED PO-TAS-SIUM (K) (MG/L)	DIS-SOLVED CHLO-RIDE (CL) (MG/L)	DIS-SOLVED SULFATE (SO4) (MG/L)	DIS-SOLVED FLUO-RIDE (F) (MG/L)	DIS-SOLVED SILICA (SIO2) (MG/L)	DIS-SOLVED ARSENIC (AS) (UG/L)	TOTAL ARSENIC (AS) (UG/L)	DIS-SOLVED BARIUM (BA) (UG/L)
06307730 - THREEMILE CREEK NEAR ASHLAND, MT. (LAT 45 30 46 LONG 106 09 25)												
JAN., 1975												
20...	8.2	18	.9	31	8.4	2.0	49	.1	6.2	4	3	--
MAR.												
19...	10	20	.9	29	7.0	2.0	67	.4	5.1	--	--	--
06307740 - OTTER CREEK NEAR ASHLAND, MT. (LAT 45 35 18 LONG 106 15 17)												
OCT., 1974												
02...	150	390	6.1	51	24	12	1100	.9	3.2	--	1	--
NOV.												
21...	180	440	6.3	50	27	16	1200	.7	7.2	--	--	--
DEC.												
19...	180	420	5.7	47	18	14	1200	.8	11	1	1	30
JAN., 1975												
10...	160	460	6.5	50	20	14	1500	.7	17	--	0	--
22...	15	30	1.2	33	8.5	3.2	100	.1	5.9	--	2	--
FEB.												
06...	95	220	3.9	44	16	8.8	690	.5	16	--	--	--
MAR.												
06...	17	26	1.0	29	10	5.2	80	.2	6.4	--	--	--

Table 23 (cont)

DATE	DIS-SOLVED BERYL-LIUM (BE) (UG/L)	TOTAL BERYL-LIUM (BE) (UG/L)	DIS-SOLVED BISMUTH (BI) (UG/L)	DIS-SOLVED BORON (B) (UG/L)	DIS-SOLVED CAD-MIUM (CD) (UG/L)	TOTAL CAD-MIUM (CD) (UG/L)	DIS-SOLVED CHRO-MIUM (CR) (UG/L)	TOTAL CHRO-MIUM (CR) (UG/L)	DIS-SOLVED COBALT (CO) (UG/L)	DIS-SOLVED COPPER (CU) (UG/L)	TOTAL COPPER (CU) (UG/L)	TOTAL IRON (FE) (UG/L)
06307730 - THREEMILE CREEK NEAR ASHLAND, MT. (LAT 45 30 46 LONG 106 09 25)												
JAN., 1975												
20...	0	<10	--	110	0	20	0	10	--	8	50	1500
MAR.												
19...	--	--	--	110	--	--	--	--	--	--	--	--
06307740 - OTTER CREEK NEAR ASHLAND, MT. (LAT 45 35 18 LONG 106 15 17)												
OCT., 1974												
02...	--	<10	--	450	--	<10	--	0	--	--	<10	720
NOV.												
21...	--	--	--	400	--	--	--	--	--	--	--	--
DEC.												
19...	<4	<10	<14	200	<50	10	<14	<10	<14	7	110	620
JAN., 1975												
10...	--	10	--	490	--	10	--	0	--	--	30	1100
22...	--	<10	--	120	--	<10	--	0	--	--	10	2900
FEB.												
06...	--	--	--	420	--	--	--	--	--	--	--	--
MAR.												
06...	--	--	--	120	--	--	--	--	--	--	--	--

Table 23 (cont)

DATE	DIS-SOLVED IRON (FE) (UG/L)	DIS-SOLVED LEAD (PB) (UG/L)	TOTAL LEAD (PB) (UG/L)	TOTAL MAN-GANESE (MN) (UG/L)	DIS-SOLVED MAN-GANESE (MN) (UG/L)	DIS-SOLVED MOLYB-DENUM (MO) (UG/L)	TOTAL MOLYB-DENUM (MO) (UG/L)	DIS-SOLVED NICKEL (NI) (UG/L)	TOTAL NICKEL (NI) (UG/L)	DIS-SOLVED SILVER (AG) (UG/L)	DIS-SOLVED STRON-TIUM (SR) (UG/L)	DIS-SOLVED VANA-DIUM (V) (UG/L)
06307730 - THREEMILE CREEK NEAR ASHLAND. MT. (LAT 45 30 46 LONG 106 09 25)												
JAN., 1975												
20...	60	6	<100	60	20	--	0	2	<50	--	--	--
MAR.												
19...	190	--	--	--	--	--	--	--	--	--	--	--
06307740 - OTTER CREEK NEAR ASHLAND. MT. (LAT 45 35 18 LONG 106 15 17)												
OCT., 1974												
02...	50	--	<100	90	--	--	4	--	<50	--	--	--
NOV.												
21...	10	--	--	--	--	--	--	--	--	--	--	--
DEC.												
19...	80	<14	100	50	45	<6	5	<14	<50	<2	1800	<10
JAN., 1975												
10...	10	--	100	100	--	--	5	--	0	--	--	--
22...	260	--	<100	60	--	--	1	--	<50	--	--	--
FEB.												
06...	310	--	--	--	--	--	--	--	--	--	--	--
MAR.												
06...	490	--	--	--	--	--	--	--	--	--	--	--

Table 23 (cont)

DATE	DIS-SOLVED ZINC (ZN) (UG/L)	DIS-SOLVED TIN (SN) (UG/L)	DIS-SOLVED ALUM-INUM (AL) (UG/L)	DIS-SOLVED GALLIUM (GA) (UG/L)	DIS-SOLVED GER-MANIUM (GE) (UG/L)	DIS-SOLVED LITHIUM (LI) (UG/L)	TOTAL LITHIUM (LI) (UG/L)	TOTAL SELE-NIUM (SE) (UG/L)	DIS-SOLVED TI-TANIUM (TI) (UG/L)
06307730 - THREEMILE CREEK NEAR ASHLAND, MT. (LAT 45 30 46 LONG 106 09 25)									
JAN., 1975									
20...	20	--	0	--	--	--	10	3	--
MAR.									
19...	--	--	--	--	--	--	--	--	--
06307740 - OTTER CREEK NEAR ASHLAND, MT. (LAT 45 35 18 LONG 106 15 17)									
OCT., 1974									
02...	--	--	--	--	--	--	130	0	--
NOV.									
21...	--	--	--	--	--	--	--	--	--
DEC.									
19...	<50	<14	90	<6	<14	150	140	2	<10
JAN., 1975									
10...	--	--	--	--	--	--	140	2	--
22...	--	--	--	--	--	--	20	1	--
FEB.									
06...	--	--	--	--	--	--	--	--	--
MAR.									
06...	--	--	--	--	--	--	--	--	--

DATE	DIS-SOLVED ZIR-CONIUM (ZR) (UG/L)	DIS-SOLVED SOLIDS (SUM OF CONSTI-TUENTS) (MG/L)	DIS-SOLVED SOLIDS (TONS PER DAY)	DIS-SOLVED SOLIDS (TONS PER AC-FT)	TOTAL NITRO-GEN (NO3) (MG/L)	DIS-SOLVED MERCURY (HG) (UG/L)	TOTAL MERCURY (HG) (UG/L)
06307730 - THREEMILE CREEK NEAR ASHLAND, MT. (LAT 45 30 46 LONG 106 09 25)							
JAN., 1975							
20...	--	149	.73	.20	5.9	.0	.0
MAR.							
19...	--	181	10.2	.25	5.1	--	--
06307740 - OTTER CREEK NEAR ASHLAND, MT. (LAT 45 35 18 LONG 106 15 17)							
OCT., 1974							
02...	--	2080	1.24	2.83	4.5	--	.8
NOV.							
21...	--	2270	18.4	3.09	5.4	--	--
DEC.							
19...	<22	2330	18.6	3.17	3.9	<.1	<.1
JAN., 1975							
10...	--	2690	18.6	3.66	6.2	--	.0
22...	--	240	84.9	.33	8.3	--	.0
FEB.							
06...	--	1350	22.7	1.84	8.0	--	--
MAR.							
06...	--	228	160	.31	9.1	--	--

Figure 9

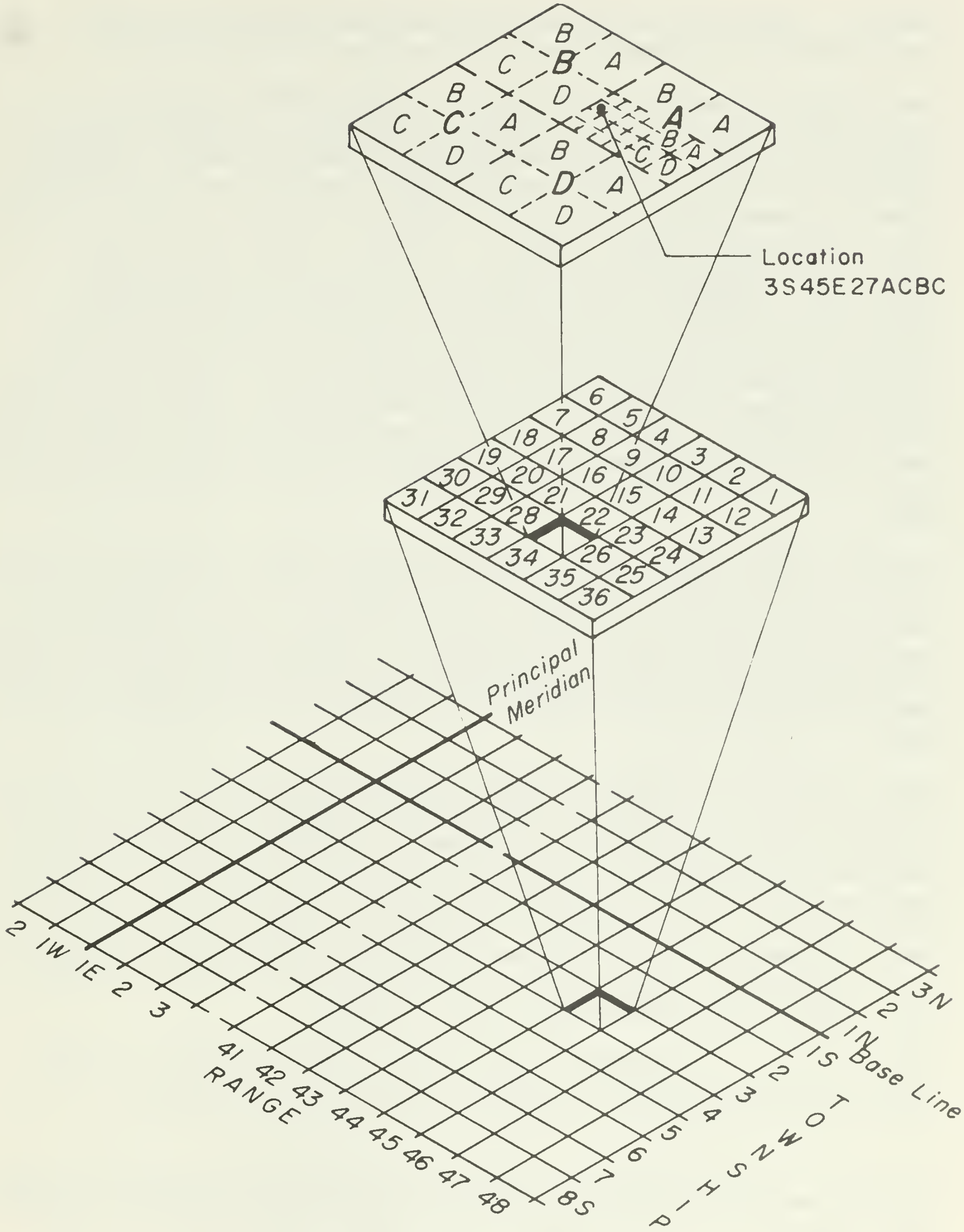


Figure 9. --System for identifying well locations

Location codes for the Bureau of Reclamation core holes and the Geological Survey observation hole are given on table 24.

The unconfined water table generally reflects the topography (plate 41). The water table slopes toward Otter Creek at gradients ranging from about 25 feet per mile to 50 feet per mile. The water table also slopes northwest and southwest toward Home and Threemile Creeks, respectively. Depth to the water measured in water wells and test holes ranges from a maximum of 230 feet along the drainage divide to 38 feet along Home Creek and 43 feet along Threemile Creek (plate 42). Water is usually available from the alluvium at a shallow depth below stream bottoms. As shown in plates 6 and 7, "Geologic sections X - Y and X - Z" and plate 42, the water table generally lies below the top of the Knoblock coal along the north and the west sides of the field. As much as 32 feet of coal lies above the saturated zone at DH 74-101. The Knoblock coal dips about 25 feet per mile to the east and the water table is 65 feet above the top of the coal at observation hole DH 75-108 in the east-central part of the area.

Drawdown and recovery tests were performed on some of the test holes and in the Knoblock. Sustained discharges from some of these wells averaged 5.3 gallons per minute. The specific capacity averaged 0.10 gallon per minute per foot of drawdown. Other wells could not sustain discharges greater than 2 gallons per minute. Transmissivities were generally less than 200 gallons per day per foot (135 square feet per day).

Some carbonaceous shale and clayey siltstone recovered in the coring of the holes were analyzed for vertical permeability. Hydraulic conductivities obtained from analyses of the fines immediately above and below the coal in DH 74-105 are 1.2×10^{-1} and 1.7×10^{-5} gallons per day per square foot (1.6×10^{-2} and 2.2×10^{-6} feet per day), respectively. The fine-grained sedimentary rocks are isolated pods and thin-bedded units in coarser material. Thin-bedded units generally are found directly above and below the coalbeds. Semi-confinement will result from pumping water from the coal.

The direction of unconfined ground-water flow generally is toward Otter, Home, and Threemile Creeks. The arrows in plate 41 also show that flow is toward the contact between the clinker and coal.

Based on a transmissivity of about 200 gallons per day per foot, the average velocity of ground-water flow through the unconfined aquifer is estimated to be 0.03 feet per day using a form of Darcy's Law.

This form of Darcy's Law assumes average conditions and is not valid for predicting the velocities of contaminants passing through the same material, because contaminants may travel along preferential pathways not typified by average conditions.

A series of confined aquifers directly underlie the Lebo Shale Member of the Fort Union Formation. Water from the Tullock Member of the

Table 24.--Geographic locations of test holes drilled by the U.S. Bureau of Reclamation at the Otter Creek coal field. See Plate 5 for USBR Drill Hole Locations.

U. S. B. R. DRILL HOLE NUMBER	GEOGRAPHIC LOCATION CODE
DH 74-101	3S45E34CACD
DH 74-102	3S45E26DBCB
DH 74-103	3S45E34AACD
DH 74-104	3S45E26ADAC
DH 74-105	3S45E34DDDA
DH 74-106	4S45E02BDDD
DH 74-107	4S45E02DADC
DH 75-108	3S45E35DABA

Fort Union Formation flows from wells along Otter Creek. Flow rates of as much as 20 gallons per minute have been reported. Because the wells flow, the potentiometric surface in the Tullock appear to be higher than in the water-table aquifer. Leakage of water from the Tullock upward to the Tongue River is small because of the relatively small difference in head and the 150-160 feet thick Lebo confining bed. The potentiometric surface in the Hell Creek Formation is about coincident with that of the Tullock. The Hell Creek is about 900 feet below land surface.

The potentiometric surface of the basal Hell Creek-Fox Hills aquifer is not defined because no wells tap the aquifer near the coal field. The basal Hell Creek-Fox Hills is an important aquifer to the north and east. In the Otter Creek coalfield, the top of the basal Hell Creek-Fox Hills aquifer lies about 1,600 feet below land surface. Aquifer thickness may be as much as 300 feet. Water would be expected to flow from wells tapping the basal Hell Creek-Fox Hills aquifer.

Water from the Judith River Formation, the Eagle Sandstone, and the Muddy Sandstone Members of the Thermopolis Shale probably would flow at land surface. The Judith River lies about 3,000 below land surface; the Eagle lies about 3,600 below land surface. The Muddy lies about 6,500 feet below land surface.

Water from the Madison Group may be available to the coalfield. The top of the aquifer is at an altitude of about 8,000 feet below land surface and the Madison is about 900 feet thick. The potentiometric surface, which dips gently to the northeast, is estimated to be about 300 feet above land surface. The Madison yields water primarily from fractures or solution openings and the number of these openings penetrated by a well determine the yield of the well. Transmissivities determined from drill-stem tests in several locations within the Powder River Basin ranged from 33.7 to 194,000 gallons per day per square foot (4.5 to 26,000 square feet per day) (Swenson, 1974).

Chemical Quality

The terms used to describe the general chemical character of surface and ground water follow the usage of Piper, Garrett, and others (1953, p. 26, footnote): (1) Calcium bicarbonate designates water in which calcium amounts to 50 percent or more of the cations, and bicarbonate amounts to 50 percent or more of the anions, in chemical equivalents; (2) sodium calcium bicarbonate designates water in which sodium and calcium are first and second in order of abundance of cations, respectively, but neither amounts to 50 percent or more of the total cations; and (3) sodium sulfate bicarbonate designates water in which sulfate and bicarbonate are first and second in order of abundance of the anions, respectively, but neither amounts to 50 percent or more of the total anions.

Chemical monitoring of Otter Creek at Ashland gaging station was begun October 10, 1974. In addition, Otter Creek was sampled three times at the Otter Creek Road bridge crossing (4S45E04BA). The major cations, anions, and dissolved solids from these analyses are listed in table 22. Excluding the analyses of water collected on January 22, 1975 and March 6, 1975, because they represent runoff due to snowmelt over frozen ground, the mean dissolved solids for the eight analyses is 2,250 mg/l (milligrams per litre). The water for the individual samples was chemically similar; either sodium sulfate or sodium magnesium sulfate in type. Chemical and spectographic analyses of samples from Otter Creek at Ashland and Threemile Creek near Ashland are presented on table 23.

Conductivity and the sodium adsorption ratio have been used by the U.S. Salinity Laboratory Staff (1954, p. 79-81), to classify water for irrigation. Conductivity (micromhos per centimetre) is a means of estimating the total concentration of soluble salts in water (salinity hazard). Water having moderate to high salt content (750 to 2,250 micromhos per centimetre), may cause accumulation of salts within soil creating a saline condition. The sodium adsorption ratio is based mainly on the effect of exchangeable sodium on the physical condition of the soil (alkalinity hazard). Alkali soils are formed by the accumulation of sodium and are often characterized by poor tilth and low permeability.

Chemical analyses of water samples collected from water-table wells and test holes indicate ground-water type is variable (table 25). Sodium bicarbonate type water was found along Home Creek in the area of clinker overlain by alluvium (3S45E26BABD) and at two wells in the coal near Threemile Creek (DH 74-106 and 74-107). Sodium sulfate and sodium magnesium sulfate type water was found along Threemile Creek in the area of clinker overlain by alluvium (4S45E04DBDB) and at one well in the coal (DH 74-103) and one well reported by the land owner to be in the coal (4S45E02CDDB). One sample of sodium sulfate bicarbonate water was found upstream from the coalfield on Threemile Creek. Study of these analyses suggest no simple correlation between chemical type and location or geology of the sampling site.

All water-table samples in the coal area were high to very high in salinity hazard; sodium hazard generally was very high to extremely high. The exception was some water samples with medium sodium hazard taken from the water-table aquifer near Threemile Creek.

All samples exceeded U.S. Public Health Service standards for drinking water in dissolved solids and dissolved sulfate concentrations (U.S. Public Health Service, 1962). However, the Public Health Service accepts non-compliance where no better supply is available. Dissolved solids concentration in samples from all test holes except DH 74-103 were below the upper limits for stock water (McKee and Wolf, 1963).

At the time water was pumped and sampled from the Knoblock coal at test hole DH 74-107, the water table was drawn down below the top of the coal. The pumped water remained very dark in appearance for at least 12 hours of pumping. A strong hydrogen sulfide odor was given off by the water sample; it effervesced freely for more than 30 minutes. Spectrographic scan of the water compared with sedimentary material

Table 25.--Chemical and spectrographic analyses of ground water in the vicinity of the Otter Creek Study Site.

WELL NUMBER		GEOLOGIC UNIT	DEPTH OF WELL (FEET)	DATE OF SAMPLE (Y-M-D)	DIS-SOLVED SILICA (SIO2) (MG/L)	DIS-SOLVED IRON (FE) (UG/L)	DIS-SOLVED MAN-GANESE (MN) (UG/L)
3S45E26BABD		Tongue River Member of Fort Union Formation	210	74-10-17	8.8	30	10
		DO	210	74-11-06	8.0	50	--
3S45E34AACD	1/	DO	140	74-11-07	10	240	--
4S45E01CDCA		DO	45	75-01-10	23	50	--
4S45E02BDDD	1/	DO	170	74-12-12	9.1	60	--
4S45E02CDDB	1/	DO	80	74-11-05	25	80	--
4S45E02DACD	1/	DO	100	75-01-10	10	60	--
4S45E04DBDB		DO	50	74-01-12	30	40	270
4S45E12ABBC		DO	41	74-11-05	13	760	--
3S45E33BCBB		Tullock Member of Fort Union Formation	900	73-12-18	8.0	0	0
3S45E33CBDA		DO	435	73-12-21	8.3	0	0

1/ Well derives water from Knoblock coal.

Table 25 (cont)

TEMPER-ATURE (DEG C)	TUR-BID-ITY (JTU)	DIS-SOLVED ARSENIC (AS) (UG/L)	DIS-SOLVED BORON (B) (UG/L)	DIS-SOLVED COPPER (CU) (MG/L)	DIS-SOLVED MERCURY (HG) (UG/L)
11.0	--	--	160	--	--
11.2	8	2	160	--	--
12.0	1200	1	260	--	--
7.0	4	0	330	5	0.3
10.5	400	6	160	--	.1
10.4	--	1	350	--	.0
12.9	80	0	130	3	.1
10.0	--	--	--	--	--
11.0	--	1	260	0	.0
12.5	--	--	--	--	--
12.5	--	--	--	--	--

Table 25 (cont)

DIS-SOLVED FLUO-RIDE (F) (MG/L)	DIS-SOLVED NITRATE (NO3) (MG/L)	TOTAL NITRITE PLUS NITRATE (N) (MG/L)	TOTAL AMMONIA NITRO-GEN (N) (MG/L)	ORGANIC NITRO-GEN (N) (MG/L)	TOTAL KJEL-DAHL-NITRO-GEN (N) (MG/L)	TOTAL NITRO-GEN (N) (MG/L)	TOTAL PHOS-PHORUS (P) (MG/L)	DIS-SOLVED ORTHO PHOS-PHORUS (P) (MG/L)
2.2	--	0.04	0.26	--	0.50	--	--	0.18
1.9	--	.07	.03	0.20	.23	0.30	0.05	--
.4	--	.12	--	.00	1.9	2.0	1.0	--
.5	--	.25	.04	.46	.50	.75	.05	--
.7	--	.02	.94	3.2	4.1	4.1	.60	--
.6	--	.83	.00	.09	.09	.92	.04	--
1.6	--	.01	.83	1.2	2.0	2.0	.29	--
.8	0.6	--	--	--	--	--	--	--
1.0	--	.15	.31	.34	.65	.80	.16	--
3.3	.4	--	--	--	--	--	--	--
3.3	.4	--	--	--	--	--	--	--

DISSOLVED CALCIUM (CA) (MG/L)	DISSOLVED MAGNESIUM (MG) (MG/L)	DISSOLVED SODIUM (NA) (MG/L)	DISSOLVED POTASSIUM (K) (MG/L)	BICARBONATE (HCO3) (MG/L)	CARBONATE (CO3) (MG/L)	DISSOLVED SULFATE (SO4) (MG/L)	ALKALINITY AS CACO3 (MG/L)	DISSOLVED CHLORIDE (CL) (MG/L)
3.2	0.2	270	2.3	680	--	1.5	554	13
2.6	1.2	260	2.7	680	1	2.9	564	14
160	50	1200	11	890	0	2200	728	18
110	120	330	13	720	0	920	588	5.3
23	12	530	7.6	870	0	500	713	11
110	140	310	12	640	0	930	522	7.2
8.3	5.5	490	3.6	1270	0	51	1040	13
90	140	360	23	610	0	1000	499	9.1
52	49	480	8.1	870	0	690	716	7.0
3.0	.2	360	1.5	790	20	1.2	718	66
2.6	.9	360	1.6	810	35	4.9	789	34

Table 25 (cont)

DIS-SOLVED SOLIDS (SUM OF CONSTI-TUENTS) (MG/L)	DIS-SOLVED SOLIDS (TONS PER AC-FT)	HARD-NESS (CA,MG) (MG/L)	NON-CAR-BONATE HARD-NESS (MG/L)	PER-CENT SODIUM	SODIUM AD-SORP TION RATIO	SPE-CIFIC CON-DUCT-ANCE (MICRO-MHOS)	PH (UNITS)
635	0.86	9	0	98	40	1040	--
632	.86	11	0	97	33	1040	8.5
4090	5.56	610	0	81	21	5600	7.3
1880	2.56	770	180	48	5.2	2500	7.7
1520	2.07	110	0	91	22	2380	8.5
1850	2.52	850	330	44	4.6	3200	7.6
1210	1.65	43	0	96	32	1820	8.0
2280	3.10	780	290	59	5.6	2590	8.2
1730	2.35	330	0	75	11	2800	7.7
1250	1.70	8	0	99	53	1380	8.5
1270	1.73	10	0	99	50	1470	8.5

from the aquifer suggests that copper, iron, and manganese may be dissolving in water entering the coal from above.

Chemically the Knoblock coal represents a reducing environment whereas the sedimentary rocks above the coal constitute an oxidizing environment. As water passes from one environment to the other, the chemical makeup of the water is altered. The exact nature of this reaction is unknown, but the results can be observed from differences in the chemical analyses of samples from above and within the coal in the vicinity of the pumped test hole DH 74-107. Water from the coal has significantly lower concentrations of dissolved solids, hardness, dissolved cations except for sodium, and sulfate than water from the unconfined aquifer above the coal. On the other hand, water from the coal has a higher concentration of bicarbonate and total nitrogen, and has a higher pH. The coal has the overall effect of improving the chemical quality of the ground water. Chemical analyses of water from above the coal are typified by analyses from well 4S45E01CDCA and 4S45E12ABBC and water from the coal by analyses from test holes DH 74-107 and DH 74-106 (table 25).

The chemical character of water from the confined, deep aquifers generally is similar to that of the water-table aquifer in dissolved solids concentration. Water from wells tapping the Tullock Member of the Fort Union Formation on the west edge of the coalfield is soft, sodium bicarbonate water with an average dissolved-solids concentration of 1260 mg/l (table 25). Chemical quality data extrapolated into the area suggests Hell Creek water is similar to Tullock water. Judith River water has dissolved-solids concentration greater than 6,000 mg/l and is sodium chloride in type. Water from the Eagle Sandstone is also sodium chloride, but is even greater in dissolved solids concentration. Water from the Muddy Sandstone Member of the Thermopolis Shale is sodium chloride sulfate type and above 5,000 mg/l in dissolved-solids concentration. Water within the Madison Group may contain nearly 2,000 mg/l dissolved solids (Swenson, 1974).

Potential Supply for Reclamation

The water needed for reclamation of the Otter Creek coalfield must be obtained from sources discussed in the foregoing sections. The quantity and quality of no single source is ideally suited to such a purpose. Therefore, the use of combinations of surface water and ground water may be necessary. In any case, surface storage of water may be necessary to maintain adequate quantities of water and to allow for treatment of water of poor chemical quality.

The only surface water available for reclamation is spring runoff. During the remainder of the year flow is non-existant along Home and Threemile Creeks; Otter Creek flow generally is less than 3 cfs. Otter Creek presently is used for flood irrigation only.

Wells in the Tongue River Member of the Fort Union Formation and the alluvium yield from 4 to 12 gpm in the Otter Creek coalfield. Regionally, alluvium along perennial streams may yield as much as 700 gpm

(Hopkins, 1973), but such yields are not known to exist locally along Otter Creek. Hopkins (1973) also reports yields of as much as 50 gpm from the clinker beds.

The deep, confined aquifers may yield more water; 20 gpm reported from a well in the Tullock Member of the Fort Union Formation. Artesian wells may be produced from virtually all of the deep, confined aquifers; heads will be at an altitude of greater than 3,000 feet.

A strip mine in the central part of the Otter Creek field would necessitate drainage of about 60 feet of saturated coal. Assuming a strip mine can be approximated by a circular discharge area having a radius of one-half mile, discharge from the mine would be about 100 gpm (Jacob and Lohman, 1952).

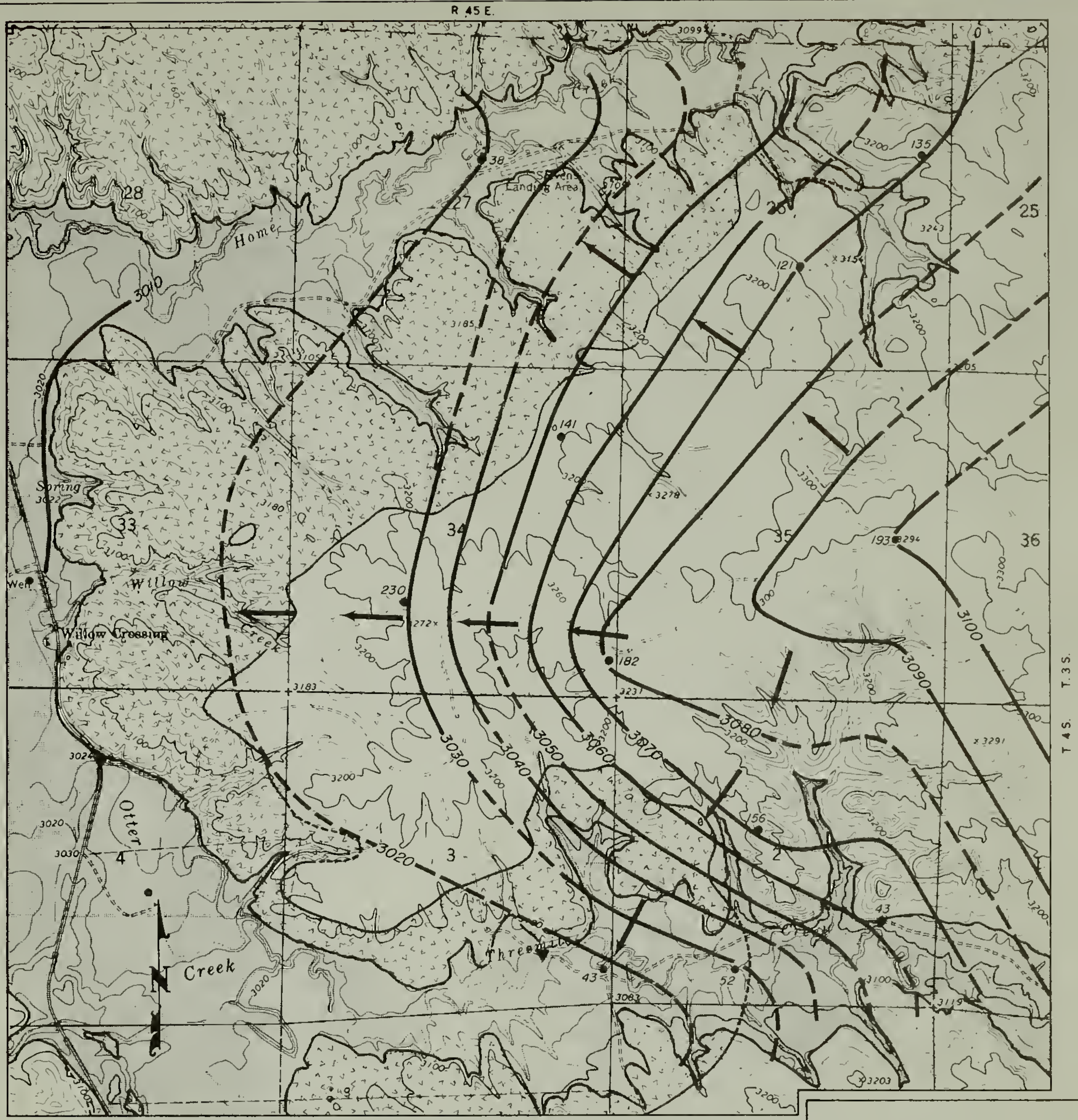
Ground-water quality generally is poor; dissolved-solids concentration range from 632 to 4,090 mg/l. Sodium hazard is medium to extremely high and salinity hazard is high to very high. Therefore, ground water is a poor source of water to irrigate spoil banks.

Stored spring runoff or spring runoff mixed with ground water would provide good water for reclamation. It would be necessary to monitor the mixing and limit the amount of ground water based on the types of reclamation vegetation.

Summary

Surface mining of the Knoblock coalbed in the Otter Creek study site will include removing 55 to 200 feet of overburden and drain water from about 60 feet of coal. The drainage may cause the water level in 6 stock wells, which are in the area, to decline by as much as 125 feet. Streamflow should not be measurably diminished or increased by the mining operation; but without special precautions mining could increase sediment production and deteriorate the quality of water that accumulates in or passes through the spoils.

The effects of mining on ground water can be minimized by locating the mine near the stream divides or by designing the strips perpendicular to channels to minimize the area of ground-water inflow from the alluvium. Alternatively, streams could be flumed around strips. Wells can be deepened to aquifers below those that will be affected by mining. Settling ponds along reaches of the stream channel adjacent to the mining operations could be used for flood control, water storage, and minimizing the sediment production from the spoil. Using the most inert, permeable part of the overburden for the lowest part of the spoil will help minimize chemical degradation of water that accumulates in the spoil and could promote recovery of the water table after mining. Toxic material should be placed in the zone that will remain unsaturated. Monitoring streamflow, quality of water, and the water level in shallow aquifers before and after mining will help insure that problems beyond those predicted will be observed before their effects become irreversible.



L E G E N D

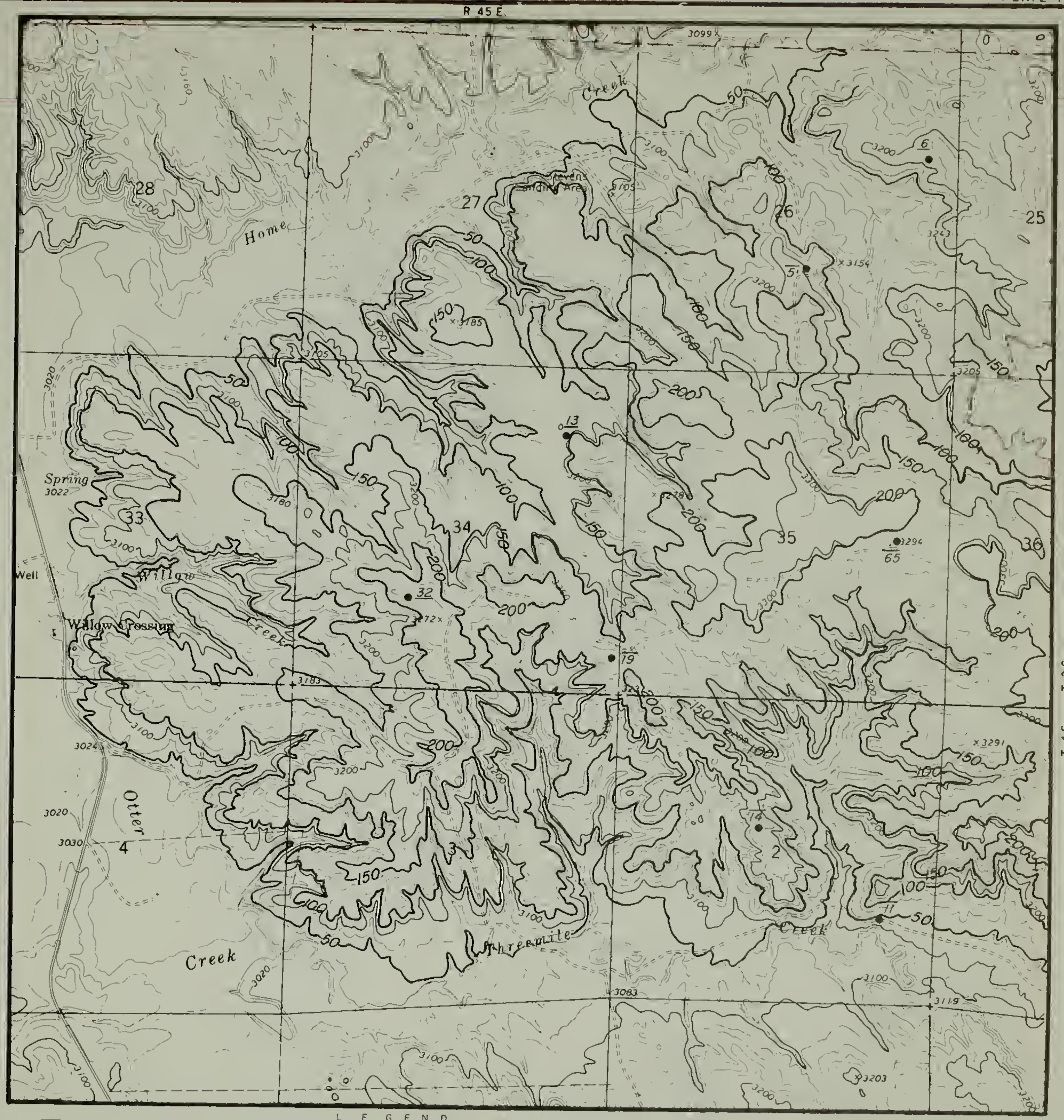
RECENT	☐	ALLUVIUM-SAND, SILT & CLAY, UP TO 50 FT. THICK.
PALEOCENE	☐	FT. UNION FM (TONGUE RIVER MEMBER) SANDSTONE, SILTSTONE, & SHALE. CONTAINS COAL BEDS UP TO 65 FT IN THICKNESS.
	⌐ ^ ⌐	CLINKER-BAKED SANDSTONE, SILTSTONE & SHALE OF THE FT. UNION FM PRODUCED BY BURNING OF THE KNOBLOCK COAL BED. UP TO 200 FT. THICK.

1000 0 1000 2000
SCALE OF FEET

——	GEOLOGIC CONTACT- DASHED WHERE INFERRED.
—3020—	WATER-TABLE CONTOUR. SHOWS ALTITUDE OF WATER TABLE DASHED WHERE APPROXIMATELY LOCATED. CONTOUR INTERVAL 10 FEET DATUM IS MEAN SEA LEVEL.
121 ●	WELL OR TEST HOLE NUMBER IS DEPTH TO WATER, IN FEET, BELOW LAND SURFACE, MARCH, 1975.
▼	SURFACE-WATER SAMPLING LOCATION
←	DIRECTION OF GROUND-WATER MOVEMENT

OTTER CREEK STUDY SITE
OTTER CREEK COAL FIELD

HYDROGEOLOGIC MAP



L E G E N D

● $\overline{19}$ TEST HOLE. NUMBER ABOVE BAR IS THICKNESS, IN FEET, OF COAL ABOVE WATER TABLE, NUMBER BELOW BAR IS DEPTH, IN FEET, TO TOP OF COAL BELOW WATER TABLE.

—50— LINE OF EQUAL DEPTH TO WATER, MARCH 1975. INTERVAL 50 FEET. DATUM IS LAND SURFACE

OTTER CREEK STUDY SITE
OTTER CREEK COAL FIELD

MAP SHOWING DEPTH TO WATER

CHARACTERIZATION OF STRATA OVERLYING COAL SEAMS AS PLANT GROWTH MEDIA

This greenhouse study was carried out in cooperation with and supplements ongoing work of the U.S. Bureau of Reclamation and U.S. Bureau of Land Management under Bureau of Reclamation Contract 14-06-D-7554 with the Colorado State University, Fort Collins, Colorado. The greenhouse study was conducted by Jim T. Herron, Graduate Assistant, under the supervision of Dr. W.A. Berg, Associate Professor of Agronomy, Department of Agronomy, Colorado State University.

Introduction

In the past, surface mining for coal generally resulted in burying of the soil and then attempts were made to revegetate the spoil. The spoil left exposed was usually from the stratum directly overlying the coal seam and often was not a suitable plant growth medium.

It is visualized that in future surface mining operations the soil will be conserved and replaced. However, on some sites the soil will be thin or less suitable as a plant growth medium than spoil generated from certain overburden strata. The objective of this study was to evaluate the suitability of overburden as a plant growth media.

Methods

Field Capacity

The initial task in the greenhouse study was to determine the field capacity of the overburden samples. The equipment used to determine field capacity was: plastic tubes 1-3/4 inches in diameter, plastic cups and plastic sheets. The cups were weighed to the nearest 0.1 gm. and the weights recorded. Three hundred grams of each overburden sample was weighed and placed in the plastic cylinders which had been sealed at the bottom by a plastic sheet. The samples were then packed by tapping the side of the cylinder. Fifteen milliliters of water was then added (5% of the overburden sample by weight) and the top was sealed with plastic. After 24 hours the bottom plastic was removed and the dry overburden fell into the cup, leaving the moist overburden in the cylinder. The weight of the cup plus dry overburden was taken and the field capacity (FC) calculated by the following equation:

$$FC\% = \frac{15gH_2O}{\text{weight of moist overburden} - 15gH_2O} \times 100$$

This field capacity percentage was the basis for the amount of water each pot received daily.

Fertilizer Treatments

Two thousand grams of overburden were weighed into each pot except where the bulk density was low or insufficient sample was available.

Each pot was fertilized with 100 ppm nitrogen as reagent grade $Ca(NO_3)_2$ and 80 ppm phosphorus as reagent grade $Ca(H_2PO_4)_2\ H_2O$. The reagents were added in solution as 10 and 50 milliliter aliquots, respectively, then mixed into the soils and overburden.

Seeding and Growth

Western Wheatgrass (Agropyron smithii var. Arriba) was the test species. This species was chosen because it is one of the most abundent native grasses in the western United States and will probably be used in revegetation programs. At the time of seeding, approximately 250 gm. of overburden was removed from each pot. Then water was added to each pot to bring them to field capacity. Thirty five seeds were placed in each pot and the removed overburden placed on the seeds. All pots were then covered with paper to retard evaporation and allow the water to move to the surface by capillary rise. The pots were checked daily and water added as needed to keep the surface moist. Germination was checked daily and upon germination, each pot was uncovered and the date recorded. The date when ten plants had emerged and the severity of salt crusting were also recorded. After germination, all pots were weighed daily and deionized water was added to bring the soil to field capacity. Maximum water use generally was about 25% of field capacity per day.

When the majority of the plants, in all pots, reached a height of about 10 cm, the number of plants in each pot was recorded and each pot was thinned to 16 plants. Photograph 5 is a general view of the greenhouse operation.

The plants were grown for 53 days, from seeding, in the first greenhouse experiment (Oct. 5 to Nov. 27, 1974) and for 52 days in the second experiment (Jan. 26 to Mar. 19, 1975).

A highly productive loam soil (Al horizon Platner series) was included in both experiments as a standard soil. The soil profile sample (W-198) from the Otter Creek study site was also included in both greenhouse experiments as standard.

In table 26, samples used in both greenhouse experiments are shown by a designation of Fall "74" for the first experiment and Winter "75" for the second experiment.

Harvesting

The plants were clipped at a height of 2 cm above the surface, washed in .05 normal HCl, and rinsed in distilled water. The plants were dried in a forced air oven at 70°C for 24 hours and then weighed to the nearest .01g.

Observations taken at the time of harvest included: (1) the presence of rhizomes, (2) the amount of black leaf tips, (3) the degree of soil surface cracking, (4) the amount of salt crusting, and (5) the average plant height.

Photograph 5 - Greenhouse studies in progress.
Colorado State University, Fort Collins, Colorado.

Additional Data

Textural analysis was run on the samples in the first greenhouse experiment to determine if the alternate wetting and drying cycles associated with watering would weather the samples and thus change the texture. It was found that there were no significant differences in texture before and after cropping.

Blackening of the leaf tips was noted in both greenhouse experiments on various samples. This blackening of leaf tips might be boron toxicity and should be investigated further.

Results and Discussion

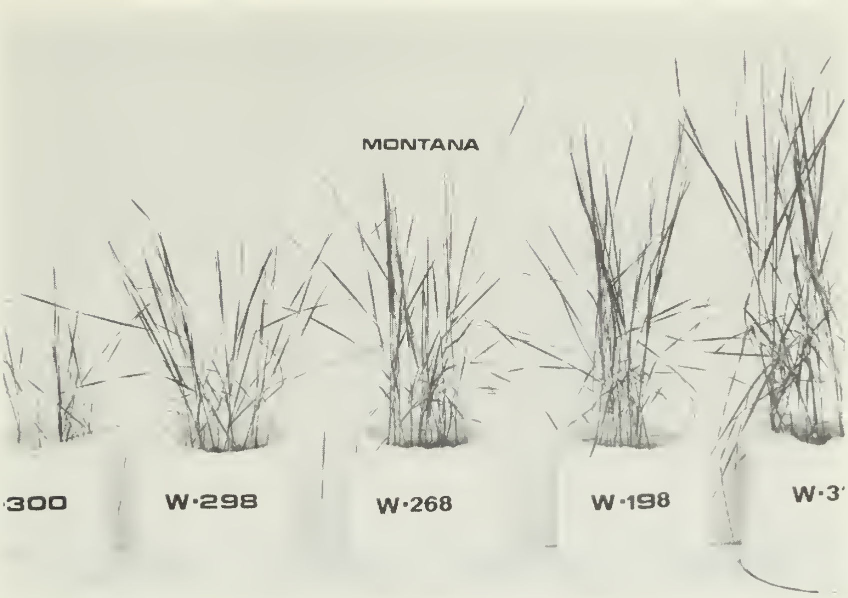
Large differences in western wheatgrass growth are evident on various overburden samples (photographs 6 and 7). For purposes of this discussion, yields of less than one gram will be considered low, yields of 1 to 2 grams medium, and above 2 grams high.

Yields on the overburden samples from the Otter Creek site in southeastern Montana were variable. The samples from the drill holes DH 74-101, DH 74-102, DH 74-103, and DH 74-104 tended to have low to medium yields (figure 10 and 11 and table 26). The samples from drill holes DH 74-105 and DH 74-106 generally had high yields (figure 12 and table 26). The Montana samples (Fort Union Formation) were generally fine-textured. Unlike the samples from Colorado and Utah, the Montana samples with high field capacities often had low yields (table 26). Many of the Montana samples were saline (EC greater than 4 mmhos) and some were probably sodic.

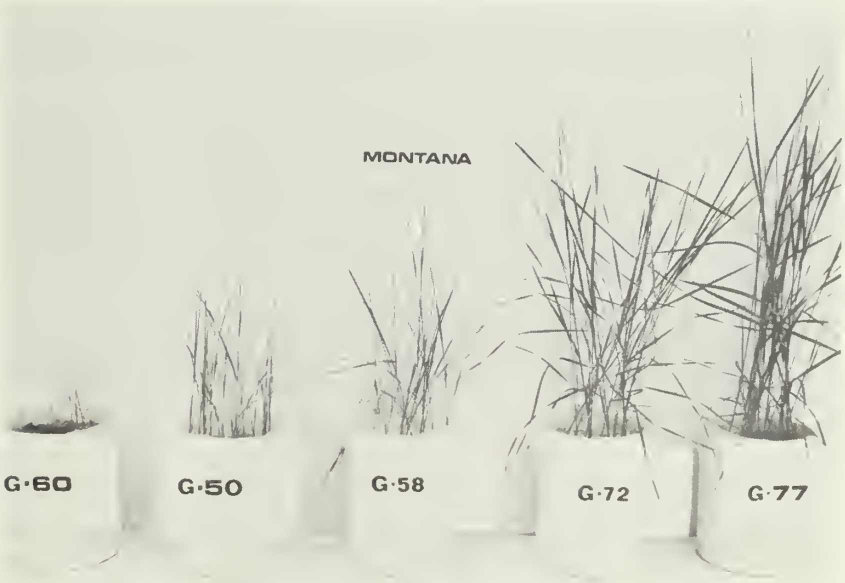
The soil profile samples from Montana produced yields which were comparable to yields on the geologic samples. Yields on the soils ranged from low to high (less than .2 to 3.5 grams) depending on the physical and chemical characteristics of the overburden (table 26).

In summary, large differences in yield were noted among overburden and soil samples. However, these results may be somewhat misleading when extrapolating to field conditions. These results reflect growth that would occur under ideal conditions as found in a greenhouse. Those overburden samples which yielded less than one gram would definitely not be suitable as plant growth media. The samples yielding more than one gram includes some strata which would make a favorable plant growth media but also includes some which would make a poor plant growth media under field conditions.

In this greenhouse study, overburden samples with the higher field capacities generally yielded the most. In the field, under arid and semi-arid conditions, these fine-textured materials would be the more drouthy soils because of greather surface runoff and evaporation. Thus, growth differences reported in this greenhouse study will give an indication of the suitability of the overburden as a plant growth media under controlled greenhouse conditions. When extrapolating these results to field conditions, the physical and chemical characteristics



Photograph 6 - Range in Western Wheatgrass growth on soil profile samples from the Otter Creek Study Site.



Photograph 7 - Range in Western Wheatgrass growth on geologic (drill core) samples from the Otter Creek Study Site.

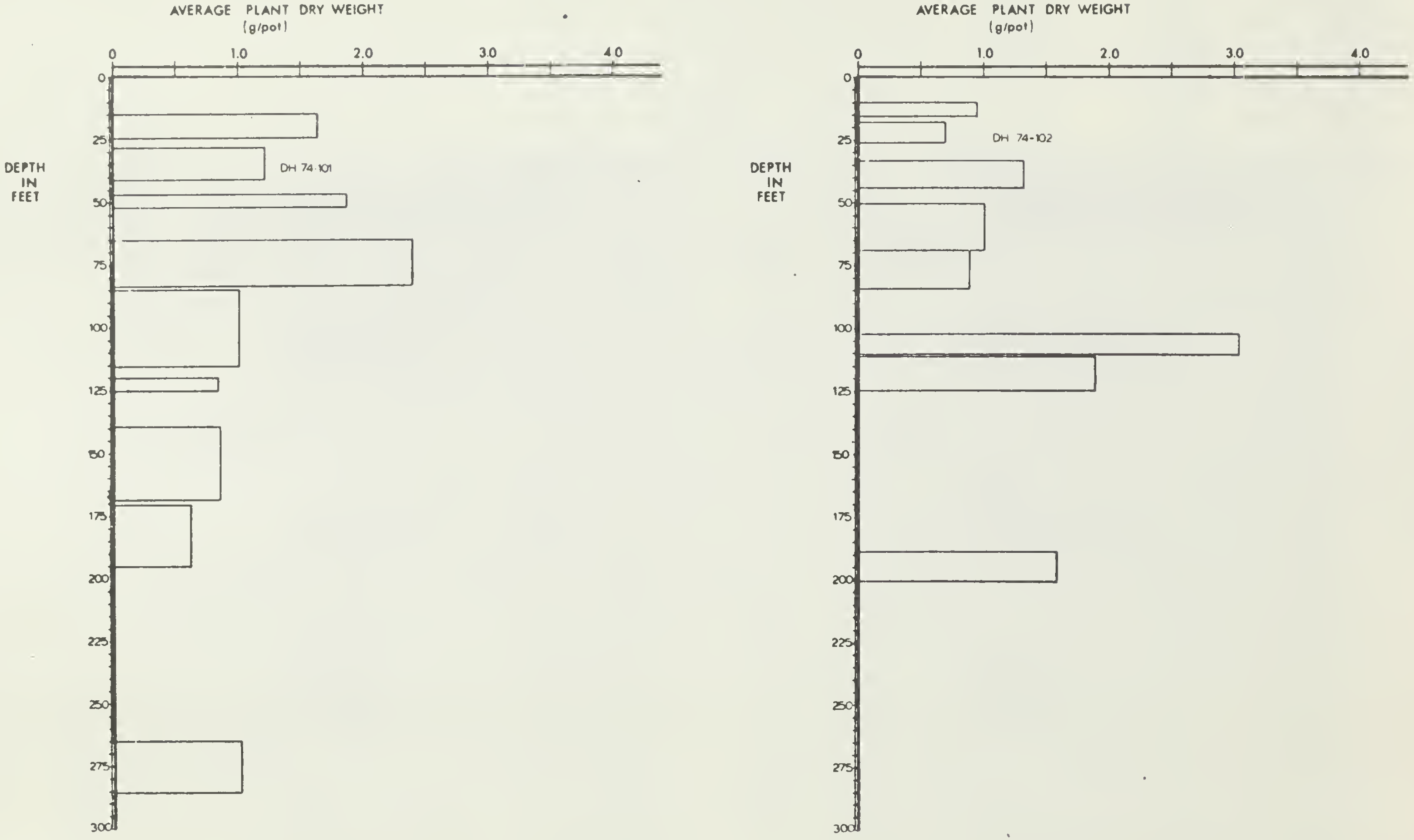


Fig 10. Yields of western wheatgrass on overburden from coreholes DH 74-101 and DH 74-102 Otter Creek site in Montena

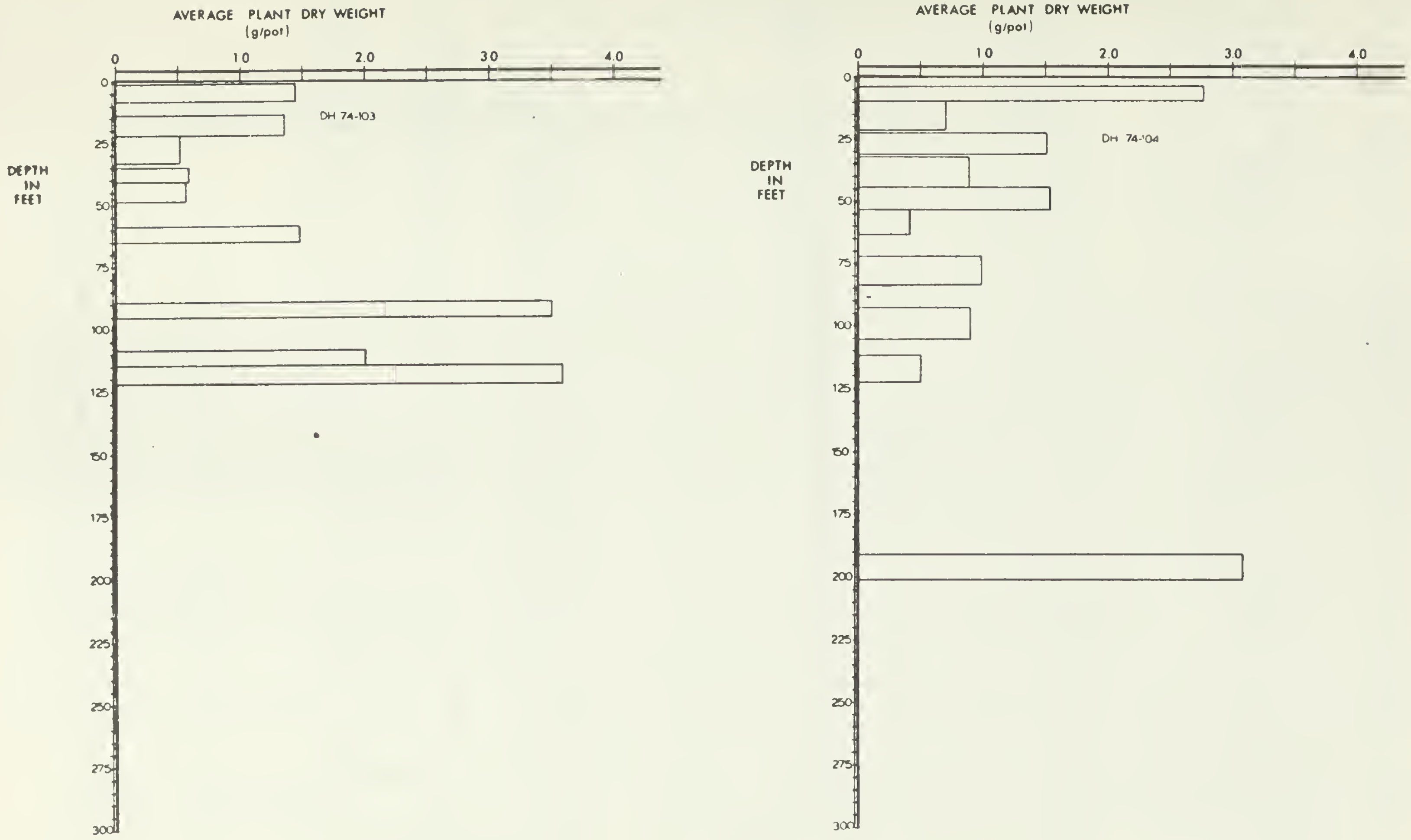


Fig. 11. Yields of western wheatgrass on overburden from coreholes DH 74103 and DH 74-104 Otter Creek site in Montana

Figure 12

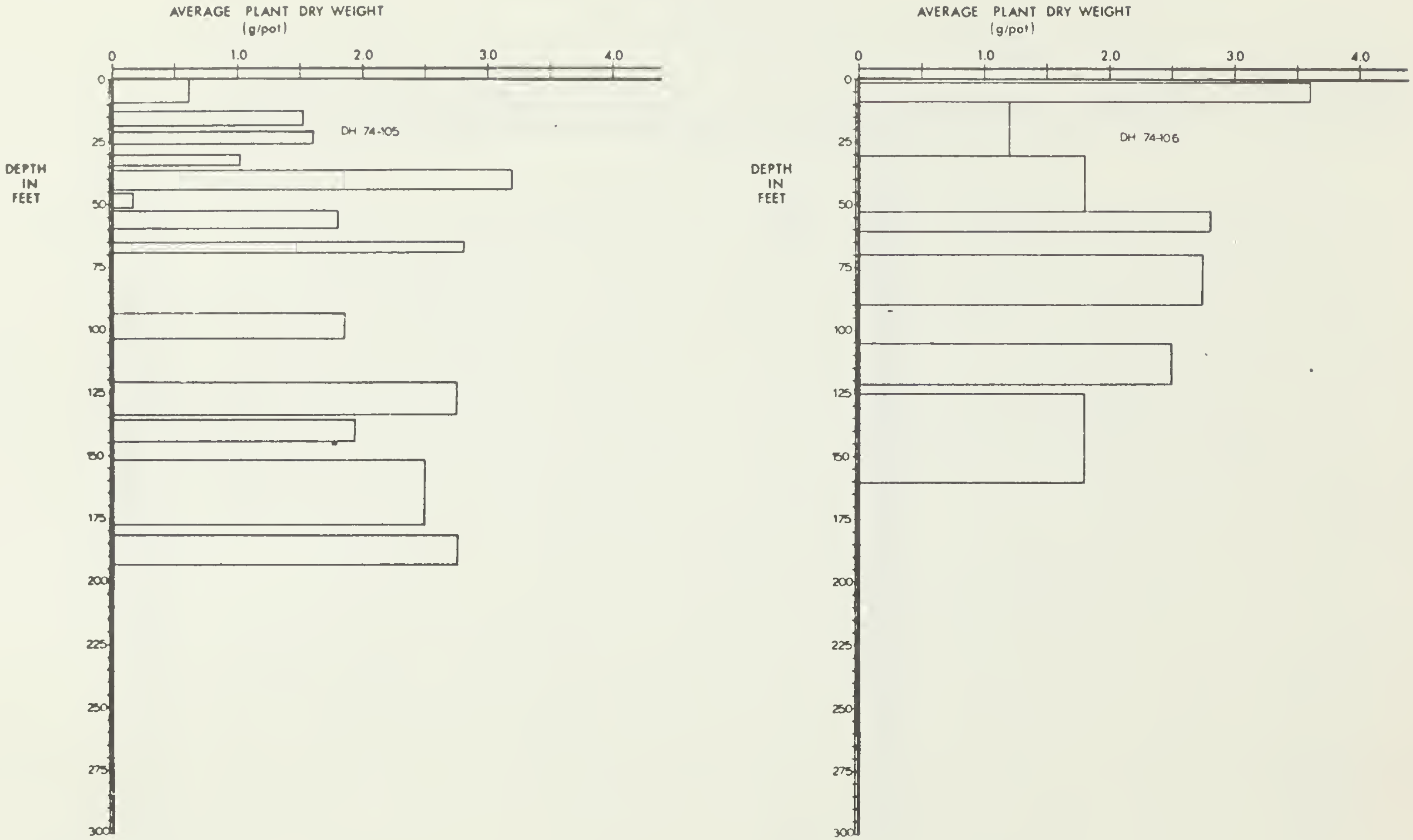


Fig.12. Yields of western wheatgrass on overburden coreholes DH 74-105 and DH 74-106 Otter Creek site in Montana

must be analyzed along with the greenhouse yield data to make interpretations of the suitability of the strata as a plant growth media.

In an attempt to correlate yield with chemical characteristics, graphs were made of yield versus electrical conductivity, cation exchange capacity, and saturation percentage. No direct correlations were found by this graphing. Multiple regressions to correlate the chemical and physical characteristics of overburden to the greenhouse yield will be run at a later date.

Explanation for Table 26.

The degree of salt crusting and surface cracking of the overburden were given a numerical designation as follows:

0 - None
1 - Very slight
2 - Slight
3 - Moderate
4 - Extreme

Blackened leaf tips were observed and frequency of occurrence, within pots, was recorded as follows:

0 - no plants with black leaf tips
1 - 1- 4 " " " " "
2 - 5- 8 " " " " "
3 - 9-12 " " " " "
4 -13-16 " " " " "

These blackened leaf tips (5-10mm) changed to a brown color after 1-2 weeks. Although the leaf tips died back, there was no evidence of overall yield reduction of plants so affected.

Bulk density of the overburden samples was calculated; this information is not recorded but is available.

Roman numerals I and II in the following tables refer to replications. Duplicate pots were run on all soil and overburden samples for which there was adequate soil material.

Table 26

GREENHOUSE DATA FOR OTTER CREEK STUDY SITE

Sample No.	Depth (ft.)	Pot wt. (Kg)	Germination				Salt Crust at Germination	Salt Crust at Harvest	Harvest				Black Leaf Tips	Soil Surface Cracks	Field Cap. %
			Days After Seeding for Ten Plants to Emerge		No. of Seeds Germinated				Plant Dry Weight (gm)		Avg. Plant Height (cm)				
			I	II	I	II			I	II	I	II			
G-2	14.4- 24.2	2	12	12	31	32	2	2	1.32	1.92	34	36	0	2	20.6
G-3	28.6- 41.3	2	8	8	28	27	0	1	1.23	1.21	30	31	0	0	25.2
G-4	47.1- 52.0	2	8	8	31	24	0	0	1.89	1.85	33	35	2	2	23.0
G-5	65.5- 78.6	2	8	8	30	32	0	0	2.43	2.31	38	35	2	2	24.4
G-6	79.8-115.2	2	6	6	31	35	3	0	1.06	0.94	29	27	0	1	9.3
G-7	119.9-125.0	2	12	12	28	11	2	2	0.92	0.81	30	29	0	1	18.6
G-8	139.0-166.5	2	7	7	31	34	0	1	0.91	0.83	28	24	0	2	7.2
G-9	171.5-198.6	2	11	11	20	10	2	1	0.65	0.58	27	26	0	1	17.2
G-10	264.0-284.5	2	6	6	32	33	0	1	1.01	1.04	28	27	0	0	7.2
G-12	9.6- 16.0	2	7	7	29	18	0	0	0.95	0.93	26	27	2	0	14.7
G-13	18.0- 26.5	2	10	12	16	15	0	1	0.59	0.76	27	23	2	0	16.6
G-14	28.0- 43.5	2	10	7	22	26	0	1	0.93	1.69	29	32	3	0	9.2
G-15	50.4- 67.5	2	5	5	34	34	0	0	1.08	0.91	30	23	3	0	6.6
G-16	67.5- 84.5	2	8	8	26	28	0	0	0.84	0.97	27	27	4	0	7.2
G-18	102.0-110.0	2	7	7	32	32	0	0	2.86	3.23	40	40	0	0	22.3
G-19	111.0-124.5	2	7	7	19	21	0	0	1.77	2.01	30	35	1	0	14.8
G-20	188.3-200.0	2	8	8	18	21	0	0	1.63	1.50	30	29	0	0	15.4
G-22	1.5- 8.5	2	6	6	22	28	1	0	1.54	1.37	30	30	1	0	24.2
G-24	13.5- 22.0	2	10	10	32	24	0	0	1.20	1.48	31	36	0	0	21.7
G-25	22.0- 33.0	2	16	14	13	18	0	0	0.49	0.51	25	20	3	0	14.9
G-26	35.0- 40.9	2	7	11	27	19	0	0	0.65	0.55	27	18	2	0	14.8
G-27	40.9- 49.0	1.75	10	11	30	19	0	0	0.68	0.44	24	20	0	0	10.3
G-29	58.3- 64.8	2	7	7	25	28	0	0	1.45	1.49	28	32	2	0	15.3
G-32	88.3- 95.3	2	5	5	33	30	0	0	3.32	3.68	39	46	0	1	24.7
G-34	107.9-114.0	2	10	10	14	22	0	0	2.07	1.93	39	39	0	0	16.1
G-35	114.0-122.0	2	6	6	33	32	0	2	3.48	3.66	40	43	0	0	24.3

Table 26 Continued

GREENHOUSE DATA FOR OTTER CREEK STUDY SITE

Sample No.	Depth (ft.)	Pot wt. (Kg)	Germination: Days After Seeding for Ten Plants to Emerge I	II	Germination: No. of Seeds Germinated I	II	Salt Crust at Germination	Salt Crust at Harvest	Harvest: Plant Dry Weight (gm) I	II	Harvest: Avg. Plant Height (cm) I	II	Black Leaf Tips	Soil Surface Cracks	Field Cap. %
G-39	4.6- 9.6	2	7	7	29	34	0	0	2.63	2.86	39	40	0	0	21.0
G-40	9.6- 21.9	2	13	9	17	27	0	0	0.41	0.97	23	26	2	0	15.9
G-41	22.6- 31.1	2	7	6	33	29	0	0	1.18	1.79	26	32	0	0	19.8
G-42	32.0- 44.8	2	8	5	25	30	0	0	0.76	0.92	26	35	1	1	17.8
G-43	44.8- 53.1	2	7	8	26	19	0	0	1.61	1.43	30	33	1	0	11.9
G-44	53.1- 62.8	2	7	7	27	32	0	1	0.36	0.45	18	17	4	0	6.5
G-46	72.8- 83.8	2	8	7	28	33	0	0	0.78	1.16	26	28	2	0	7.8
G-48	93.2-105.5	2	12	7	11	27	0	2	0.81	0.97	26	27	4	0	12.1
G-50	111.7-121.7	2	12	11	14	22	0	0	0.45	0.54	23	21	1	0	14.5
G-52	191.2-200.7	2	6	6	35	34	0	0	2.74	3.41	42	40	1	0	22.9
G-55	0 - 8.6	2	8	10	27	34	0	0	0.63	0.58	28	21	3	2	18.3
G-56	12.9- 18.3	2	9	7	27	34	0	0	1.34	1.60	28	31	0	0	17.7
G-57	20.6- 25.8	2	7	6	24	30	0	0	1.50	1.65	31	31	0	0	13.0
G-58	30.4- 34.3	2	7	7	17	25	0	0	0.90	1.14	27	29	1	0	6.9
G-59	36.3- 44.0	2	5	5	35	35	0	0	2.13	3.19	41	43	0	0	24.7
G-60	45.3- 51.3	2	10	7	16	30	4	4	0.16	0.15	9	6	0	1	17.9
G-61	52.6- 59.8	2	6	6	33	32	0	0	1.77	1.81	36	36	0	0	22.3
G-63	65.2- 69.1	2	5	5	33	32	0	0	2.61	3.01	39	36	1	3	26.2
G-66	93.3-103.0	2	5	6	27	32	0	0	1.53	2.16	33	33	0	2	31.6
G-68	120.7-128.0	2	5	5	33	34	0	0	2.69	2.81	37	41	0	2	29.9
G-70	135.6-143.9	2	5	5	33	32	0	0	1.86	1.98	33	33	0	2	38.2
G-72	151.8-177.0	2	5	5	33	32	0	0	2.48	2.52	40	39	0	0	24.3
G-74	181.6-192.7	2	5	5	31	33	0	0	2.57	2.88	39	37	0	3	23.6
G-77	1.0- 9.0	2	5	5	33	33	0	2	3.04	4.16	43	42	0	0	22.4
G-78	9.0- 30.5	2	7	7	32	33	0	0	1.12	1.25	27	30	1	2	19.3
G-79	30.5- 52.5	2	5	5	22	33	0	0	1.94	2.01	36	35	3	0	16.3
G-80	52.5- 60.5	2	6	6	35	34	0	0	2.62	3.00	41	39	0	0	21.8
G-82	69.2- 88.8	2	5	5	33	33	0	1	2.91	2.56	37	39	0	0	24.8
G-84	104.8-121.5	2	5	5	28	35	0	0	2.26	2.69	39	37	0	0	30.9
G-86	125.2-160.1	2	5	5	28	31	0	0	1.58	2.01	30	36	2	2	27.8

Table 26 Continued

GREENHOUSE DATA FOR OTTER CREEK STUDY SITE

			Germination						Harvest						
Sample No.	Depth (in.)	Pot wt. (Kg)	Days After Seeding for Ten Plants to Emerge I	II	No. of Seeds Germinated I	II	Salt Crust at Germination	Salt Crust at Harvest	Plant Dry Weight (gm) I	II	Avg. Plant Height (cm) I	II	Black Leaf Tips	Soil Surface Cracks	Field Cap. %
W-105	18- 30	2	7	7	33	34	0	0	1.97	2.11	32	35	2	1	18.3
W-106	30- 56	2	7	7	34	32	0	0	1.43	1.41	31	29	0	0	20.6
W-110	14- 30	2	7	7	32	34	0	0	2.10	1.94	34	34	3	1	18.2
W-111	30- 40	2	10	10	25	24	0	2	0.83	0.84	25	30	0	0	19.8
W-113	8- 24	2	6	6	33	32	0	0	1.98	2.35	34	30	2	0	13.4
W-115	44- 62	2	6	7	30	26	0	0	2.74	2.65	37	41	2	0	23.0
W-123	8- 16	2	7	7	33	30	0	0	2.68	2.28	36	35	3	0	16.2
W-125	30- 58	2	7	7	35	32	0	0	1.32	1.44	31	30	2	1	16.1
W-196	16- 24	2	7	7	29	31	0	0	0.79	0.88	28	28	4	0	16.2
W-198	32- 60	2	7	7	35	33	0	0	1.81	1.77	33	33	0	1	15.5
W-201	88-112	2	7	7	32	33	0	0	2.41	1.76	33	33	0	1	17.1
W-198	32- 60	2	7	7	32	29	0	0	1.76	2.03	32	35	0	0	15.1
Winter "75"															
W-118	24- 36	2	7	7	30	31	0	0	1.30	1.29	34	30	3	0	12.9
W-121	93-114	2	7	7	34	34	0	0	1.49	1.40	29	29	0	1	14.0
W-127	14- 32	2	6	6	34	30	0	0	1.94	1.75	32	30	3	0	12.2
W-129	60- 84	2	6	6	29	33	0	4	2.56	2.33	35	34	3	0	16.5
W-131	102-120	2	5	5	35	34	0	0	2.07	2.02	35	31	0	0	12.8
W-134	22- 40	2	6	6	34	35	0	0	1.90	1.94	34	29	4	1	14.9
W-136	64- 86	2	6	6	32	33	0	0	1.61	1.65	32	32	0	0	17.1
W-138	6- 22	2	7	7	29	28	0	0	1.75	1.68	32	33	3	1	16.3
W-140	40- 60	2	7	7	29	30	0	0	1.08	1.22	27	30	3	1	18.5
W-148	12- 36	2	6	6	33	32	1	0	2.85	2.75	36	38	4	1	18.2
W-149	36- 60	2	7	7	30	30	0	0	1.55	1.62	32	30	4	1	17.1

Table 26 Continued

GREENHOUSE DATA FOR OTTER CREEK STUDY SITE

Sample No.	Depth (in.)	Pot wt. (Kg)	Germination				Salt Crust at Germination	Salt Crust at Harvest	Harvest				Black Leaf Tips	Soil Surface Cracks	Field Cap. %
			Days After Seeding for Ten Plants to Emerge		No. of Seeds Germinated				Plant Dry Weight (gm)		Avg. Plant Height (cm)				
			I	II	I	II			I	II	I	II			
W-153	12- 36	2	6	6	33	35	0	0	2.91	2.70	38	32	0	1	13.1
W-155	51- 84	2	6	6	33	32	0	0	2.54	2.56	36	33	2	1	17.5
W-167	40- 64	2	8	8	24	15	0	2	0.74	0.82	25	24	3	0	22.7
W-172	48- 72	2	7	7	34	33	0	0	1.18	1.23	30	28	2	1	17.3
W-174	84-108	2	6	6	31	29	0	0	1.23	1.55	31	32	0	1	15.3
W-181	0- 16	2	6	6	35	33	0	0	2.84	2.62	38	37	2	1	14.1
W-184	31- 72	2	9	9	28	24	0	0	0.44	0.43	17	17	3	0	11.1
W-185	72-102	2	8	8	24	25	0	0	0.41	0.48	21	21	0	0	10.5
W-189	32- 44	2	6	6	34	28	3	0	0.92	1.07	26	26	0	1	22.5
W-192	72- 90	2	9	9	28	29	4	1	0.14	0.22	10	8	0	2	19.3
W-193	100-118	2	7	7	28	24	4	1	0.12	0.12	8	7	0	2	18.1
W-205	28- 44	2	7	7	28	26	0	0	1.10	1.33	30	30	4	0	15.8
W-207	52- 76	2	8	8	27	29	0	0	1.34	1.39	30	30	2	0	15.7
W-209	104-120	2	8	8	27	31	0	0	1.01	0.58	29	22	0	0	14.5
W-218	28- 44	2	7	7	33	32	0	0	1.64	1.58	31	32	0	1	16.2
W-220	50- 66	2	9	9	23	23	2	2	0.51	0.69	26	25	3	0	12.6
W-226	0- 12	2	7	7	33	32	0	0	2.69	2.68	35	37	0	0	14.7
W-228	30- 48	2	6	6	30	34	0	0	1.37	1.17	31	29	2	0	11.7
W-229	48- 64	2	12	12	30	29	2	2	0.29	0.26	15	16	0	0	16.7

Table 26 Continute

GREENHOUSE DATA FOR OTTER CREEK STUDY SITE

Sample No.	Depth (in.)	Pot wt. (Kg)	Germination: Days After Seeding for Ten Plants to Emerge I	Germination: Days After Seeding for Ten Plants to Emerge II	Germination: No. of Seeds Germinated I	Germination: No. of Seeds Germinated II	Salt Crust at Germination	Salt Crust at Harvest	Harvest: Plant Dry Weight (gm) I	Harvest: Plant Dry Weight (gm) II	Harvest: Avg. Plant Height (cm) I	Harvest: Avg. Plant Height (cm) II	Black Leaf Tips	Soil Surface Cracks	Field Cap. %
W-236	36- 60	2	7	7	33	32	0	2	1.17	1.23	27	28	0	1	18.9
W-268	3- 8	2	6		35		0	2	2.00		36		1	0	14.6
W-269	8- 16	2	6	6	32	33	0	1	2.68	2.40	37	39	1	1	17.5
W-270	16- 27	2	5	5	33	32	0	0	2.62	2.92	42	40	1	0	22.8
W-298	48- 72	2	7	6	33	32	0	0	1.13	1.55	28	29	2	0	16.3
W-300	98-120	2	10	15	27	16	0	0	0.64	0.54	22	26	0	0	12.5
W-314	8- 30	2	5	5	33	34	0	0	2.82	3.11	42	37	0	0	19.4
W-316	54- 76	2	6	6	32	33	0	0	3.46	3.43	43	43	0	0	27.2
W-318	92-120	2	6	5	35	34	0	0	1.84	2.42	37	37	0	0	16.8

Table 27

GREENHOUSE DATA FOR STANDARD SOIL

			Germination						Harvest						
			Days After Seeding for Ten Plants to Emerge		No. of Seeds Germinated				Plant Dry Weight (gm)		Avg. Plant Height (cm)				
Sample No.	Depth (ft.)	Pot wt. (Kg)	I	II	I	II	Salt Crust at Germination	Salt Crust at Harvest	I	II	I	II	Black Leaf Tips	Soil Surface Cracks	Field Cap. %
Standard loam Soil Fall 1974		2	6	6	33	32	0	0	3.28	3.34	41	39	0	0	15.2
Standard loam Soil Winter 1975		2	6	6	35	33	0	0	3.20	2.84	36	36	0	0	15.2

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APPENDIX

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION–SOIL DESCRIPTION

1. State 25	2. District 02	3. Planning Unit LZ	4. Vegetation–Soil Unit mixed grasses, 9009	5. Soil Map Symbol 89/ArM	6. Surname Ward	7. Date 07 mo 74 yr
8. Area --	9. County 075	10. Location Sec. 26, T. 3S, R. 45E	11. Photo No.	12. Writeup No. 1	13. File No.	14. Parent Rock Alluvium

15. Formation Name: Fort Union
16. Surface Conditions (percent): Stone – 0 Rock – 0
17. Land Conditions: Alkaline High (Subsoil) Saline moderate (Subsoil) Water table > 10'
18. Landform: Flood plain
19. Slope (percent) 0/2 ☒ Single ☐ Complex
20. Aspect: NW
21. Elevation: 3120'
22. Present Erosion: Type SSF Class 1
23. Hydrologic Group: –
24. Precipitation (in) 13.7 1st, 2nd, 3rd, 4th
25. Temperature: Air Soil
26. Frost-free: Days 130 > 28°
27. Drainage Class: Mod-welldrained
28. Infiltration: moderate
29. Percolation: moderate to slow
30. ERD: 16 in
31. AWC: 9.2 in

32. HORIZON	33. THICKNESS	34. COLOR DRY / MOIST: MATRIX	MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH) 1-5 CaCl2	42. BOUNDARY
A1	0-2	D-(2.5Y 7/2) m-(2.5Y 6/2)		L	fine granular	D-soft m-friable	None	many		+++ 8.5 [illegible]	Diffuse
AC	2-14	D-(2.5Y 7/2) m-(2.5Y 6/2)		L	fine & med granular	D-soft m-friable	None	many		+++	Clear wavy
C1ca	14-28	D-(2.5Y 8/4) m-(2.5Y 7/4)		Hv fSL	fragmental to weak mass.	D-Hard m-friable	None	many		+++ 9.2 8.2	Abrupt
C2ca	28-44	D-(10YR 7/2) m-(10YR 6/3)		fSL	weak massive	D. sli hard m-friable		com, to few		+++ 9.2 8.3	
C3	44-52	D-(10YR 7/2) m-(10YR 6/3)		VfSL	weak massive	D sli hard m-friable		few to none		++ 9.1 8.3	
C4ca	52-76	D-(10YR 7/2) m-(10YR 6/3)		VfSL		D- m-friable				+++ 8.9 8.2	
C5ca	76-104	D-(10YR 7/1) m-(10YR 6/3)		SiL		D- m-friable				+++ 8.8 8.2	
C6ca	104-120	D-(2.5Y 8/2) m-(2.5Y 7/3)		Lt SiL		m-friable				+++ 8.8 8.3	

A fair to good stand of western wheat, blue grama, green needle, and prairie june grass, covers most of the area. Silver occurs at random through the area. This soil is quite erosive, wind and water if exposed.

Salinity and alkalinity stat[illegible] 28"

(Instructions inside back cover)

Form 7310–9 (December 1970)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION–SOIL DESCRIPTION

1. State 25	2. District 02	3. Planning Unit 12	4. Vegetation–Soil Unit Mixed Grasses 1-900.5	5. Soil Map Symbol 85/AZM	6. Surname Ward	7. Date 07 mo 74 yr
8. Area --	9. County 075	10. Location Sec. 26, T. 3S, R. 45E	11. Photo No. ----------	12. Writeup No. 2	13. File No. ------	14. Parent Rock Colluvium and interbedded siltstone and shale

15. Formation Name Fort Union	16. Surface Conditions *(percent)* Stone – 0 Rock – 0	17. Land Conditions Alkaline moderate (subsoil) Saline mod. to high (subsoil) Water table > 5'	18. Landform Collurial slope in Rolling hills
19. Slope *(percent)* 2-4 ☒ Single ☐ Complex	20. Aspect E / 21. Elevation 3150'	22. Present Erosion Type SSF --- Class 2	23. Hydrologic Group -

24. Precipitation *(in)* 13.7 1st , 2nd , 3rd , 4th	25. Temperature -- Air -- Soil	26. Frost-free Days 130 > 28°	27. Drainage Class Mod. welldrained	28. Infiltration moderate	29. Percolation moderate	30. ERD 10 in	31. AWC 7.2 in

32. HORIZON	33. THICKNESS	34. COLOR DRY / MOIST MATRIX	MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH) 1-5 CaCl2	42. BOUNDARY
A1	0-12	D-(10yR 8/2) m-(10yR 7/3)		SiL	platy	D- Hard m- friable		many	None	++ 8.5 7.7	Clear wavy
ACca	12-16	D-(10YR 8/3) m-(10YR 7/4)		SiL	weak ang Blky to med gran.	D- Sli Hard m- friable		com.	None	+++ 8.5 8.0	clear
C1ca	16-20	D-(10yR 8/3) m (10yR 7/6)		Lt SiCL	med sub ang. blocky	D- Sli Hard m- Friable		few		+++ 8.6 8.2	Abrupt
C2	20-36	D (2.5Y 8/2) m (2.5Y 7/3)		Lt SiCL	Decomposed Silty shale	D Hard m friable		few		++ 8.8 8.3	
C3	36-50	D-(2.5Y 8/2) m-(2.5Y 7/3)		SiL	Decomposed Silty shale	D soft m friable		few to none		++ 8.9 8.4	
C4	50-64	D- 2.5Y 8/3) m-(2.5Y 7/6		SiL	consolidated Silty shale	D Hard m- friable				8.8 8.3	

Poor stand of green needle, and western wheatgrass covers part of the area. This profile located in a most adverse spot below a soft siltstone exposure. Although this profile is not typical it is typical of many small tracts below shale, siltstone and some sandstone exposures.

Salinity and alkalinity starts at 20"

(Instructions inside back cover)

Form 7310-9 (December 1970)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION-SOIL DESCRIPTION

1. State 25	2. District 02	3. Planning Unit 12	4. Vegetation–Soil Unit mixed grasses – / – 9009	5. Soil Map Symbol ~~09~~ AIM	6. Surname Ward	7. Date 07 mo 74 yr
8. Area 2	9. County 075	10. Location Sec. 26, T. 3S, R. 45E	11. Photo No.	12. Writeup No. 3	13. File No.	14. Parent Rock Colluvium, alluvium and interbedded siltstone + shale
15. Formation Name Fort Union	16. Surface Conditions (percent) Stone – 0 Rock – 0	17. Land Conditions Alkaline Mod to high (subsoil) Saline Mod to high (subsoil) Water table				18. Landform Colluvial slope between narrow flood plains
19. Slope (percent) 0/2 ☒ Single ☐ Complex	20. Aspect N	21. Elevation 3150'	22. Present Erosion Type SSF – – – Class –			23. Hydrologic Group –
24. Precipitation (in) 13.7 1st , 2nd , 3rd , 4th	25. Temperature – – Air – – Soil	26. Frost-free Days 130 > 28°	27. Drainage Class Mod. well drained	28. Infiltration moderate	29. Percolation slow	30. ERD 12 in / 31. AWC 10.5 in

32. HORIZON	33. THICKNESS	34. COLOR DRY/MOIST MATRIX	MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH) 1-5 CaCl2	42. BOUNDARY
										N	
A1	0-2	D-(10YR 7/2) m-(10YR 4/3)		Hv SiL	platy	D-soft m friable	None	Many			abrupt
B2	2-8	D-(10YR 7/3) m (10YR 4/3)		Lt SiCL	mod Prismatic	D Hard m-very firm	thin Patchy	Many		8.2 7.4	clear
C1	8-28	D-(10YR 7/4) m (10YR 6/4)		Lt SiCL	fine sub ang blky	D-sli Hard m-firm		many to com.		8.7 7.9	abrupt
C2	28-44	D-(10YR 7/3) m-(10YR 6/4)		Lt SiCL	Massive	m-friable		com to few		8.7 8.1	Gradual
C3	44-50	D-(10YR 8/3) m-(10YR 7/6)		Lt SiCL	Massive	m-friable		few to none		8.5 8.1	abrupt
C4	50-66	D-(10YR 8/2 m-(10YR 4/2)		SiL	Consolidated siltstone	Hard in place friable out				8.7 8.2	
C5	66-72	D-(10YR 7/2) m-(10YR 5/6)		SiL	"	Very Hard in place				8.7 8.3	
					stopped by hard siltstone						

A fair to good stand of western wheat, blue grama, and prairie june grass covers most of the area. Slick spots and exposed soft siltstone occur locally. Vegetation cover between slick spots ranges from poor to fair. Profile No. 18 records the soil condition in a slick spot. This soil is unstable and erosive, water and wind where unprotected by vegetation. Silver sage occurs in small groups and single plants. Salinity starts at 44" + Salinity [illegible] at 50"

(Instructions inside back cover)

Form 7310–9 (December 1970)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION–SOIL DESCRIPTION

1. State 25	2. District 02	3. Planning Unit 12	4. Vegetation–Soil Unit Mixed grasses, 9003	5. Soil Map Symbol $\frac{03}{B3H}$	6. Surname Ward	7. Date 07 mo 74 yr
8. Area —	9. County 075	10. Location Sec. 26, T. 3S, R. 45E	11. Photo No.	12. Writeup No. 4	13. File No.	14. Parent Rock Colluvium & clayey shale Interbedded siltstone

15. Formation Name: Fort Union
16. Surface Conditions (percent): Stone – 0 Rock – 0
17. Land Conditions: Alkaline High (subsoil) Saline High (subsoil) Water table > 5'
18. Landform: Residual slope in rolling hills
19. Slope (percent) 4/8 ☐ Single ☒ Complex
20. Aspect: SW
21. Elevation: 3205'
22. Present Erosion: Type SSF — Class 3
23. Hydrologic Group: –
24. Precipitation (in) 13.7 1st, 2nd, 3rd, 4th
25. Temperature: — Air — Soil
26. Frost-free: Days 130 > 28°
27. Drainage Class: Mod-well drained
28. Infiltration: very slow
29. Percolation: very slow
30. ERD: 8 in
31. AWC: 7.5 in

32. HORIZON	33. THICKNESS	34. COLOR DRY MOIST MATRIX	34. MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH) 1-5 CaCl2	42. BOUNDARY
A1	0-2	D- (10YR 7/2) m- (10YR 6/2)		L	platy	D- Soft m- friable	None	many		N	clear
B2t	2-11	D-(10YR 7/3) m(10YR 5/2)		MC	med Prismatic	D- Hard m very firm.	few Patchy	many to comm.		N 8.7 7.9	wavy
C1	11-24	D-(10YR 7/3) m-(10YR 6/4)	fine threads of lime	L+C	Ang blky to fine + med gran	D- Hard m- friable		com to few		++ 8.6 8.3	gradual
C2	24-48	D- (10YR 7/3) m- (10YR 6/3)	very fine chips of orange siltstone	L+C	massive	D Hard m- friable		few to none		++ 8.6 8.3	abrupt
C3ca	48-60	D- (10YR 7/1) m- (10YR 6/2	very fine chips of orange siltstone and black shale	Hv.CL	slightly weathered shale	D sli'hard m- firm				+++ 8.6 8.2	

A fair to good stand of western wheat, slender and scattered plants of green needle and needle and thread grass covers most of the area. The vegetative cover is adequate to prevent severe water erosin. Other soils included in the area are silty red soil in a burned (minor) area and rocky soils associated with silty shales. A small area of Ponderosa Pine/grass complex. This soil/vegetation has attained a level of erosional stability.

Alkalinity starts at 11" and Salinity & alkalinity at 24"

(Instructions inside back cover)

Form 7310–9 (December 1970)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION–SOIL DESCRIPTION

1. State 25	2. District 02	3. Planning Unit L2	4. Vegetation–Soil Unit Mixed grasses – – / – 9005 – –	5. Soil Map Symbol – 03/63M	6. Surname – – – Ward – – –	7. Date 07 mo 74 yr
8. Area – –	9. County 025	10. Location Sec. – 26, T. – 3S, R. 45E	11. Photo No. – – – – – –	12. Writeup No. – – – – 5	13. File No. – – – – – –	14. Parent Rock Colluvium and Interbedded siltstone + shale

15. Formation Name Fort Union	16. Surface Conditions (*percent*) Stone – 0 Rock – 0	17. Land Conditions Alkaline low to Mod. (subsoil) Saline low to mod (subsoil) Water table > 6'	18. Landform Residual/colluvial slopes; Rolling hills
19. Slope (*percent*) 3–8 ☐ Single ☒ Complex	20. Aspect – E 21. Elevation – 3165'	22. Present Erosion Type SSF – – – Class 3	23. Hydrologic Group –

24. Precipitation (*in*) 13.7 1st , 2nd , 3rd , 4th	25. Temperature – – Air – – Soil	26. Frost-free Days 130 > 28°	27. Drainage Class Mod. well drained	28. Infiltration Mod to slow	29. Percolation mod to slow	30. ERD 15 in	31. AWC – 2.4 in

32. HORIZON	33. THICKNESS	34. COLOR DRY / MOIST: MATRIX	34. MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH) 1-5 CaCl2	42. BOUNDARY
A1	0-2	D-(10YR 7/2) m-(10YR 5/3)		L	Med platy to granular	D-soft m-friable	None	many	none	+++	clear
C1ca	2-6	D-(10YR 8/2) m-(10YR 7/2)		L	med sub ang blky to gran.	D-soft m-friable	none	many	none	+++ 8.6 7.7	abrupt
C2ca	6-12	D-(10YR 7/3) m-(10YR 5/4)		fSCL	Med sub ang blky to Med gran	D-Hard m-friable	None	many	none	+++	abrupt
C3ca	12-30	D-(10YR 7/3) m (10YR 5/4)	lime threads and (10YR 4/8)	SiL	massive	D-Hard m-friable	none	many to few	none	+++ 8.6 7.9	gradual
C4ca	30-48	D-(10YR 7/3) m-(10YR 5/4)		SiL	massive	D-Hard m-friable	none	few to none	none	+++ 8.5 7.8	abrupt
C5	48-64	D- m-Layered (10YR 6/1) (10YR 5/6) (10YR 5/2)		SiCL	Consolidated Si shale	Hard in place				N 8.3 8.1	

A good stand of slender wheat, needleand thread, blue grama and green needle grass covers most of the area. This complex slope comprises many hills, rock outcrops, shallow to shale ridges. This soil is susceptable to water erosion if exposed. Active erosion occurs along animal trails, below shale exposures, and on shallow steep slopes.

Salinity and Alkalinity starts at 48"

(*Instructions inside back cover*)

Form 7310–9 (December 1970)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION–SOIL DESCRIPTION

1. State 25	2. District 02	3. Planning Unit L2	4. Vegetation–Soil Unit mixed grasses, 9007	5. Soil Map Symbol 07/A2N	6. Surname Ward	7. Date 07 mo 74 yr

8. Area —	9. County 075	10. Location Sec. 26, T. 3S, R. 45E	11. Photo No.	12. Writeup No. 6	13. File No.	14. Parent Rock Interbedded sandstone siltstone and shale

15. Formation Name Fort Union	16. Surface Conditions (*percent*) Stone – 0 Rock – 0	17. Land Conditions Alkaline moderate (subsoil) Saline Mod to high (subsoil) Water table >5'	18. Landform Tabular divide

19. Slope (*percent*) 0/3 ☒ Single ☐ Complex	20. Aspect N	21. Elevation 3260'	22. Present Erosion Type SSF – – – Class 2	23. Hydrologic Group –

24. Precipitation (*in*) 13.7 1st , 2nd , 3rd , 4th	25. Temperature – – Air – – Soil	26. Frost-free Days 130 > 28°	27. Drainage Class Mod. well drained	28. Infiltration Mod to Slow	29. Percolation Slow	30. ERD 12 in	31. AWC 6.8 in

32. HORIZON	33. THICKNESS	34. COLOR DRY/MOIST MATRIX	MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (*pH*)	42. BOUNDARY
A1	0-4	D-(10YR 7/3) m-(10YR 3/3)		fSL	fine granular	D-Soft m-friable	None	many	None	N	abrupt
B2t	4-14	D-(10YR 5/3) m-(10YR 3/4)		L	strong med columnar	D-Hard m-firm	common on many peds	Many	None	N	abrupt
C1	14-30	D-(10YR 6/4) m-(10YR 4/2)		Lt fSCL	med to fine angular	D-Hard m-very firm		many to few	None	N	clear
C2	30-36	D-(10YR 6/3) m-(10YR 4/2)		Lt fSCL	massive	D-Hard m-friable		few to none		+++	abrupt
C	36-64	D- m-(10YR 6/3 and 10YR 5/6)		SiCL	Decomposed layered silty shale	D Hard m firm				+++	

Salinity + Alkalinity starts at 30"

A poor stand of western wheat, needle and thread, blue grama, and prairie junegrass covers most of the arc not in active slick spots. This profile is located on a tabular divide but the solonetzic condition extents into foot slopes also. Slick spots are less common on the slopes but on the eroded end of ridges they are very prominent and are still highly sodic. On the foot slopes and the tabular divides the sodium has migrated downward but the structure and physical condition remains.

Active slick spots are still sodic at a shallow depth.

Salinity starts at 14". Alkalinity at 36"

(*Instructions inside back cover*)

Form 7310–9 (December 1970)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION–SOIL DESCRIPTION

1. State 25
2. District 02
3. Planning Unit 12
4. Vegetation–Soil Unit Mixed grasses, 9003
5. Soil Map Symbol 03 B2N
6. Surname Ward
7. Date 28 mo 74 yr
8. Area --
9. County 075
10. Location Sec. 26, T. 3S, R. 45E
11. Photo No. ----------
12. Writeup No. 2
13. File No. ------
14. Parent Rock Colluvium and inter-bedded siltstone and shale
15. Formation Name Fort Union
16. Surface Conditions *(percent)* Stone – 0 Rock – 0
17. Land Conditions Alkaline high (subsoil) Saline high (subsoil) Water table > 5'
18. Landform Residual slope - Rolling hills
19. Slope *(percent)* 3/6 ☒ Single ☐ Complex
20. Aspect SW
21. Elevation 3190'
22. Present Erosion Type SSF --- Class 2
23. Hydrologic Group -
24. Precipitation *(in)* 13.7 1st , 2nd , 3rd , 4th
25. Temperature -- Air -- Soil
26. Frost-free Days 130 > 28°
27. Drainage Class Mod. well drained
28. Infiltration high to m[illegible]
29. Percolation slow
30. ERD 10 in
31. AWC 4.1 in

32. HORIZON	33. THICKNESS inches	34. COLOR DRY MOIST MATRIX	34. MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH) 1-5 CaCl2	42. BOUNDARY
A1	0-2	D-(10YR 7/2) m-(10YR 6/3)		fSL	Platy	D- Soft m. friable	None	Many	None	7.8 7.5	Clear, smooth
AC	2-8	D-(10YR 7/3) m-(10YR 6/4)		Hv fSL	med Ang Blocky	D- Sl. Hard m- friable	None	many		8.2 7.6	wavy
C1	8-16	D-(10YR 6/3) m-(10YR 5/3)		Lt SiCL	strong prismatic	D- Very Hard m- Very firm		many		8.4 8.7	Clear Wavy
C2	16-22	D-(10YR 7/3) m-(10YR 6/4)	lime in pockets lower part of zone	Lt. SiCL	med + fine ang Blocky	D-Hard m- Very firm		Common		8.5 8.2	Abrupt
C3	22-40	D (2.5Y N8/0) m (2.5Y 6/2)	D (10YR 6/2) m-(10YR 4/3)	Hv SiL	Consolidated siltstone	D- m.		Common to few		8.4 8.1	
C4	40-48	M (2.5Y N8/0) m (2.5Y 7/0)	D (7.5YR 8/4) m-(7.5YR 7/8)	Lt SiCL							

[Salinity and alkalinity starts at 16"]

Slender wheat, G needle, P June, Threadleaf sedge (Carex) B grama, Big Sage (A 3d) silver Sage, Sage is scattered. At the foot of the slope are slick spots. They represent about 5 percent of the area. The 22/40 layer of silt stone will weather ~~moderately~~ rapidly though it has thin layers of more resistant material. The 40/48 layer is composed of gray and bright dark yellow. both are resistent to weathering but, the yellow is harder. The upper of the area slope is moderate to sparsely vegetated. Slope gradient ranges from 10 to 30%. and scattered stones are common in localized spots

(Instructions inside back cover)

Form 7310-9 (December 1970)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION–SOIL DESCRIPTION

1. State 25
2. District 02
3. Planning Unit 12
4. Vegetation–Soil Unit mixed grasses 900A
5. Soil Map Symbol 04/ATM
6. Surname Ward
7. Date 08 mo 74 yr
8. Area –
9. County 075
10. Location Sec. 26 T. 3S R. 45E
11. Photo No. ––––––––––
12. Writeup No. 8
13. File No. ––––––
14. Parent Rock Alluvium and interbedded sandstone, siltstone & shale
15. Formation Name Fort Union
16. Surface Conditions (percent) Stone – 0 Rock – 0
17. Land Conditions Alkaline mod. to high (subsoil) Saline mod. (subsoil) Water table > 10'
18. Landform Tabular divide
19. Slope (percent) 3/6 ☒ Single ☐ Complex
20. Aspect N
21. Elevation 3225'
22. Present Erosion Type SSF – – – Class 1
23. Hydrologic Group –
24. Precipitation (in) 13.7 1st, 2nd, 3rd, 4th
25. Temperature – – Air – – Soil
26. Frost-free Days 130 > 28°
27. Drainage Class Mod. well drained
28. Infiltration Mod to high
29. Percolation Mod. to slow
30. ERD 16 in
31. AWC 9.0 in

32. HORIZON	33. THICKNESS	34. COLOR DRY MOIST MATRIX	MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH) 1-5 CaCl₂	42. BOUNDARY
A11	0-2	D – (10YR 7/3) m – (10YR 6/3)		fSL	crumb	D soft m. friable	None	many	None		clear
A12	2-6	D – (10YR 7/5) m – (10YR 5/3)		fSL	weak med & fine gran.	D soft m – friable		many		7.8 7.5	clear wavy
B2	6-18	D – (10YR 7/4) m – (10YR 4/3)		fSL	weak prismatic	D sli hard m friable		many			clear wavy
C1	18-28	D – (10YR 7/2) m – (10YR 6/3)		fSL	weak massive	D. soft m. friable		many to com		8.4 7.9	diffuse
C2	28-44	D (10YR 7/3) M (10YR 6/4)		Lt fSL	weak massive	D – soft m – friable		com to few		8.8 8.1	
C3	44-60	D – (10YR 7/3) m – (10YR 4/4)	small shot size spots (10YR 3/1)	Lt fSL	weak massive	D – soft m. friable		few to none		8.9 8.0	
C4	60-70	D – m – (2.5Y N8/)		Lt SiCL	consolidated silty shale					8.3 8.1	
C5	70-96	D – m – (2.5Y 8/8)		Lt SiCL	soft & hard siltstone					8.4 8.3	
C6	96-108	D – m – (2.5Y 8/4)		Lt SiCL	silty shale	Salinity & alkalinity starts at 60"				8.8 8.3	
C7	108-112	D – m – (2.5Y N8/)		Lt SiCL	hard siltstone						

The alluvial material here was part of or eroded from higher alluvial deposits that are now found as small remnants on the high undulating divides. Weatherability of consolidated Fort Union formation here – 60-70" readily; 70-96" 10-20% hard, balance readily 96-108" readily, and 108-112" very slowly.

(Instructions inside back cover)

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U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION–SOIL DESCRIPTION

1. State 25
2. District 02
3. Planning Unit L2
4. Vegetation–Soil Unit [illegible] grasses, 9004
5. Soil Map Symbol 04 ~~BZM~~
6. Surname Ward
7. Date 08 mo 74 yr
8. Area –
9. County 075
10. Location Sec. 26, T. 3S, R. 45E
11. Photo No. ––––––––––
12. Writeup No. 9
13. File No. ––––––
14. Parent Rock Local Alluvium Interbedded siltstone & shale
15. Formation Name Fort Union
16. Surface Conditions *(percent)* Stone – 0 Rock – 0
17. Land Conditions Alkaline Non Saline Non Water table
18. Landform Alluvial valley in rolling Hills
19. Slope *(percent)* 3/6 ☐ Single ☒ Complex
20. Aspect N
21. Elevation 3155
22. Present Erosion Type SSF – – – Class –
23. Hydrologic Group –
24. Precipitation *(in)* 13.7 1st , 2nd , 3rd , 4th
25. Temperature – – Air – – Soil
26. Frost-free Days 130 > 28°
27. Drainage Class Well drained
28. Infiltration [illegible]
29. Percolation [illegible]
30. ERD 16 in
31. AWC 10.0 in

32. HORIZON	33. THICKNESS	34. COLOR DRY MOIST: MATRIX	34. MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH) 1-5 CaCl2	42. BOUNDARY
A1	0-3	D-(10YR 7/1) m-(10YR 6/3)		L	platy	D- soft m- friable		many	-	++ 8.4 7.5	Clear smooth
AC	3-16	D-(10YR 7/2) M-(10YR 6/3)		L	med granular	D soft m friable		many			gradual
C1	16-22	D-(10YR 7/1) m-(10YR 6/2)	Lime on stones and in pockets	L	fine sub. ang blky	D- Sli Hard m- friable		many	10-20 siltstone shards		Clear wavy
C2	22-40	D-(10YR 6/1) m-(10YR 5/2)	many very small pockets of lime	L	med ang. blky	D sli Hard m friable		many to com		++ 8.1 7.8	abrupt
C3	40-78	D-(10YR 7/3) m-(10YR 6/3)		Lt CL		D- Hard m- friable		few to none		++ 8.0 7.8	
C4	78-102	D-(10YR 7/2 m-(10YR 6/4)		SiL		D- soft m- friable				+++ 8.5 8.0	
C5	102-126	D-(10YR 7/2) m-(10YR 6/4)		SiL		D- Soft m- friable				+++ 8.6 7.9	
C6	126-156	D-(10YR 7/2) m-(10YR 6/4)		SiL		D- Soft m- friable				+++ 8.6 8.0	

The upper 40 inches of the profile appears to be from mixed sources, old alluvium and local shales. Below 40" the color and degree of weathering indicate the material is largely from old alluvium. A good stand and growth of mixed grasses include B. grama, S needle, slender wheat, western wheat and Prairie June. A few forbes and S. Sage are in the area. At least one colony of Buffalo grass is in the area.

(Instructions inside back cover)

Form 7310-9 (December 1970)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION–SOIL DESCRIPTION

1. State 25
2. District 02
3. Planning Unit 12
4. Vegetation–Soil Unit mixed grasses, 9507
5. Soil Map Symbol 07 A3N
6. Surname Ward
7. Date 28 mo 24 yr
8. Area --
9. County 075
10. Location Sec. 26 T. 3S R. 45E
11. Photo No. ----------
12. Writeup No. 10
13. File No. ------
14. Parent Rock Colluvium and interbedded Siltstone and shale
15. Formation Name Fort Union
16. Surface Conditions (percent) Stone – 0 Rock – 0
17. Land Conditions Alkaline moderate (Subsoil) Saline mod to high (Subsoil) Water table > 6'
18. Landform Tabular divide
19. Slope (percent) 0/2 ☒ Single ☐ Complex
20. Aspect N
21. Elevation 3262
22. Present Erosion Type SSF --- Class 2
23. Hydrologic Group -
24. Precipitation (in) 13.7 1st, 2nd, 3rd, 4th
25. Temperature -- Air -- Soil
26. Frost-free Days 130 > 28°
27. Drainage Class Mod. well drained
28. Infiltration medium
29. Percolation [illegible]
30. ERD 12 in
31. AWC 7.2 in

32. HORIZON	33. THICKNESS	34. COLOR DRY MOIST: MATRIX	34. MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH) 1-5 CaCl2	42. BOUNDARY
A2	0-3	D-(10YR 7/3) m-(10YR 4/3)		vfsL	Platy	D soft m friable	None	many		W 6.6 6.6	wavy
B2tA	3-8	D (10YR 6/4) m (10YR 3/4)		L	strong fine blky	D-hard m-very firm	thin patchy	many		W 7.0 6.6	Clear wavy
B3t	8-16	D-10YR 7/3) m-(10YR 4/3)		lt sicl	strong med columnar	D very Hard m-very firm	moderate in tubes	Many		W 7.3 7.0	gradual
C1	16-27	D-(10YR 6/3) m(10YR 4/3)		lt sicL	mod to fine angblky	D-very Hard m-very firm		many to few		W 8.2 7.9	diffuse
C2CA	27-36	D (2 [illegible] 8/2) m-(2 [illegible])		Lt sicl	weakly massive	D- soft m- friable		few none		+++ 8.3 8.3	Clear wavy
C3CA	36-64	A {(2.5Y 7/8) (2.5Y 6/4)		sicL	consolidated silty shale			none		+++ 8.4 8.2	

This profile is located on a tabular divide. The delineation includes the side slopes to the west and north west with similar soils.
- (10a) is located on NNE slope, has very good vegetative cover, but the shale
a gray silty material was encountered at 24"
Slick spots occur near 10, at NW edge of area and east of 10a

Salinity starts at [illegible] alkalinity at 27"

(Instructions inside back cover)

Form 7310–9 (December 1970)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION–SOIL DESCRIPTION

1. State 25
2. District 02
3. Planning Unit 12
4. Vegetation–Soil Unit mixed grasses - 9207
5. Soil Map Symbol 81/A2N
6. Surname Ward
7. Date 02 mo 74 yr
8. Area --
9. County 075
10. Location Sec. 26, T. 3S, R. 45E
11. Photo No. DWZ-1HH185
12. Writeup No. 11
13. File No. ------
14. Parent Rock silty Shale
15. Formation Name Fort Union
16. Surface Conditions (percent) Stone – 0 Rock – 0
17. Land Conditions Alkaline Mod to high Saline mod Water table > 3'
18. Landform Tabular divide
19. Slope (percent) 2-4 ☒ Single ☐ Complex
20. Aspect NW
21. Elevation 3200'
22. Present Erosion Type SSF Class 2
23. Hydrologic Group -
24. Precipitation (in) 13.7 1st, 2nd, 3rd, 4th
25. Temperature -- Air -- Soil
26. Frost-free Days 130 > 28°
27. Drainage Class Mod well drained
28. Infiltration very slow
29. Percolation very slow
30. ERD 7 in
31. AWC 3.0 in

32. HORIZON	33. THICKNESS	34. COLOR DRY MOIST MATRIX	MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH) 1-5 CaCl2	42. BOUNDARY
A2	0-2	D-(10YR 7/2) m-(10YR 6/4)		vfSL	fine crumb	D- soft m friable	None	many	None	N 8.7 8.2	clear wavy
B2t	2-6	D-(10YR 5/3) m-(10YR 4/4)		CL	Mod strong Columnar	D- Hard m- firm	thin Patchy	many		N	Gradual
C1Ca	6-12	D-(10YR 8/2) m-(10YR 7/3)		LtCL	fine sub ang Blky	D- Sli Hard m- firm		many to com		+++	gradual
C2Ca	12-16	D-(10YR 8/4) m-(10YR 7/4)		LtSiCL	weathered silty shale	D- sli Hard m- firm		com to few		+++ 9.2 8.4	
C3Ca	16-36	D m (5Y 7/1)	m-(2.5Y 7/6)	LtSiCL	Consolidated silty shale	D- m-				++ 9.0 8.2	

A good stand of mixed grasses including p. June, side oats grama, slender wheat B grama. Some forbes and silver sage were noted. The top 2" of the prisims in the 2-6" horizon are rounded and roots are largely between columns. The consolidated siltstone is largely gray with thin layers (.5 to 2") of hard silt stone. This hard material was only slightly calcareous.

Salinity starts at 6". Alkalinity 12"

(Instructions inside back cover)

Form 7310-9 (December 1970)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION–SOIL DESCRIPTION

1. State 25
2. District 02
3. Planning Unit 12
4. Vegetation–Soil Unit Mixed prairie, 9009
5. Soil Map Symbol 09/63H
6. Surname Ward
7. Date 08 mo 74 yr
8. Area --
9. County 075
10. Location Sec. 26, T. 3S, R. 45E
11. Photo No. ----------
12. Writeup No. 12
13. File No. ------
14. Parent Rock Silty shale
15. Formation Name Fort Union
16. Surface Conditions (percent) Stone – 0 Rock – 0
17. Land Conditions Alkaline Slight to mod (Subsoil) Saline High (subsoil) Water table > 12'
18. Landform Colluvial slopes – rolling hills
19. Slope (percent) 2-4 ☐ Single ☒ Complex
20. Aspect SW
21. Elevation 3160'
22. Present Erosion Type SSF --- Class 2
23. Hydrologic Group –
24. Precipitation (in) 13.7 1st , 2nd , 3rd , 4th
25. Temperature -- Air -- Soil
26. Frost-free Days 130 > 28°
27. Drainage Class Very well drained
28. Infiltration Mod. to slow
29. Percolation Mod. to slow
30. ERD 10 in
31. AWC 12.0 in

32. HORIZON	33. THICKNESS	34. COLOR DRY / MOIST: MATRIX	34. MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH) 1-5 CaCl2	42. BOUNDARY
A1	0-1	D- (5Y 8/1) m- (5Y 8/4)		SiL	platy	D- soft m- friable	None	many	None	+++	clear smooth
AC	2-12	D- (5Y 8/1) m- (5Y 8/4)		SiL	weak massive	D- soft m- friable	None	many		8.1 7.8	diffuse
C2	12-20	D- (2.5Y 8/2) m- (2.5Y 7/3)		SiL	weak Massive	D- soft m- friable		Many to com			abrupt
C3	20-26	D- (10YR 7/2) m- (10YR 6/2)		L	fine granular	D soft m- friable		com to few		+++ 8.3 8.2	clear wavy
C4	26-36	D- (10YR 6/4) m- (10YR 5/3)		L	fine & med blky	D- soft m- friable		few		+++ 8.5 8.5	
C5	36-48	D- (10YR 8/3) m- (10YR 7/3)		CL		D- Sl. hard m- friable		few to none		+++ 8.4 8.3	
C6	48-62	D- (10YR 8/1) m- (10YR 7/4)		CL		D- m friable				+++ 8.3 8.3	
C7	62-64	D- (10YR 8/1) m- (10YR 7/1)		VfSL	Consolidated sandstone	D- m- friable					

The fair to good stand of mixed grasses includes Bgrama, Sideoats grama, G needle wwheat and Pr June. Scattered Big + Silver sage. A narrow alluvial deposit along a intermittent natural drain received raw colluvial overwash from the local silty shale. This material covered a weakly developed profile 20 to 36.

Salinity and alkalinity start at 2i"

(Instructions inside back cover)

Form 7310–9 (December 1970)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION–SOIL DESCRIPTION

1. State 25
2. District 02
3. Planning Unit 12
4. Vegetation–Soil Unit mixed grass - 9605
5. Soil Map Symbol 05/B2M
6. Surname Ward
7. Date 08 mo 74 yr
8. Area –
9. County 075
10. Location Sec. 26, T. 3S, R. 45E
11. Photo No. –
12. Writeup No. L3
13. File No. –
14. Parent Rock Colluvium and interbedded siltstone and shale
15. Formation Name Fort Union
16. Surface Conditions (percent) Stone – 0 Rock – 0
17. Land Conditions Alkaline Non Saline slight (subsoil) Water table > 5'
18. Landform Colluvial slope in rolling hills
19. Slope (percent) 4-8 ☒ Single ☐ Complex
20. Aspect NW
21. Elevation 3185'
22. Present Erosion Type SSF – – – Class 2
23. Hydrologic Group –
24. Precipitation (in) 13.7 1st , 2nd , 3rd , 4th
25. Temperature – – Air – – Soil
26. Frost-free Days 130 > 28°
27. Drainage Class mod well drained
28. Infiltration moderate
29. Percolation Moderate
30. ERD 14 in
31. AWC 14.0 in

32. HORIZON	33. THICKNESS	34. COLOR DRY MOIST MATRIX	MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH) 1-5 - CaCl2	42. BOUNDARY
A1	0-2	D-(10YR 7/2) m-(10YR 5/2)		Lt Si L	Platy grading to fine gran	D - soft m- friable		Many		N 6.6 6.8	Clear Smooth
AC	2-8	D-(10YR 7/3) m-(10YR 5/2)		Si L	mod & fine ang Blky	D hard m firm		Many		N	Clear wavy
C1	8-16	D (10YR 7/3) m (10YR 5/3)		Si L	Massive	D Hard m firm		Many		N 6.7 6.8	diffuse
C2Ca	16-19	D (10YR 7/3) m(10YR 6/4)		Si L	weak massive	D soft m friable		many		++	
C3Ca	19-36	D (10YR 8/3) m(10YR 7/4)		Si L		D soft m friable		many to com		+++ 7.8 7.4	
C4Ca	36-57	D(10YR 8/3) m(10YR 7/4)		Si L		D soft m friable		com to few		+++ 8.5 8.0	

The lower horizons consist of well weathered colluvium some scoria flakes from 19 to 36" and a moderate amount from 36-57". Stopped by a sandstone shard. The Big Sage was killed by spraying and young silver sage plants are quite numerous. Shale was found at 36" about 300 feet east. The profile is on the same slope. Salinity [illegible] at 36"

(Instructions inside back cover)

Form 7310–9 (December 1970)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION–SOIL DESCRIPTION

1. State 25
2. District 02
3. Planning Unit 12
4. Vegetation–Soil Unit Needlegrass - 1 - 2222 -
5. Soil Map Symbol 02 E8N
6. Surname Ware
7. Date 02 mo 7 - yr
8. Area 1
9. County 075
10. Location Sec. - 26, T. - 3S, R. 45E
11. Photo No. - - - - - - - - - - -
12. Writeup No. - - 14
13. File No. - - - - - - -
14. Parent Rock Colluvium and interbedded sandstone, siltstone and shale
15. Formation Name Fort Union
16. Surface Conditions (percent) Stone – 0 Rock – 0
17. Land Conditions Alkaline Non Saline Mod to high (Subsoil) Water table 7 10'
18. Landform Colluvial slope in rolling hills
19. Slope (percent) 6/18 ☒ Single ☐ Complex
20. Aspect SW
21. Elevation - 3200'
22. Present Erosion Type SSF - - - Class 2
23. Hydrologic Group -
24. Precipitation (in) 13.7 1st , 2nd , 3rd , 4th
25. Temperature - - Air - - Soil
26. Frost-free Days 130 -> 28°
27. Drainage Class Well drained
28. Infiltration mod. etc
29. Percolation mod. to slow
30. ERD 19 in
31. AWC 12.2 in

32. HORIZON	33. THICKNESS	34. COLOR DRY MOIST MATRIX	MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH) 1-5 CaCl2	42. BOUNDARY
A1	0-2	D- 10YR 7/2 m (10YR 5/3)		fSL	thick plates breaks to crumb	D-Soft m friable	None	Many		7.7 7.3	clear smooth
AC	2-8	D (10YR 7/2) m (10YR 5/3)		Hv fSL	med sub ang Blky	D- Soft m friable	None	Many			clear wavy
C1	8-14	D (10YR 7/4) m (10YR 5/3)		fSCL	med sub ang blocky	D- Sli Hard m friable	None	Many		7.9 7.5	diffuse
C2	14-30	D (10YR 6/3) m (10YR 5/3)	Lime in threads and on peds	Lt fSCL	Co ang blky	D Sli Hard m friable		Many		8.0 7.6	wavy
C3	30-48	D (10YR 7/3) m (10YR 6/4)		Lt fSCL	weak massive	m Sli hard m friable		com to few		8.4 8.2	
C4	48-72	D (10YR 8/2) m (10YR 6/3)	Lime occurs in pockets	Hv fSL		m friable		few to [illegible]		8.7 8.3	
C5	72-98	m (2.5Y 8/1) m - 2.5Y 7/2)		Hv fSL		m friable				8.4 8.1	
C6	98-120	D - (10YR 8/1) m (10YR 7/3)	m (10YR 7/1)	SiL	Consolidated silty shale					8.4 8.2	
					firm to 9'						
					Hard 9 to 10'	Salinity starts at 30"					

This slope is well vegetated but shows considerable erosion in localized spots looks a little like small slump areas. Vegetation composed of B grama, S wheat so grama, G needle, silver sage. Surrounding ridges are shallow to shale. The timbered area consists of massive sandstone ledges and blocks and small spots of good soil.

(Instructions inside back cover)

Form 7310–9 (December 1970)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION–SOIL DESCRIPTION

1. State 25
2. District 02
3. Planning Unit 12
4. Vegetation–Soil Unit mixed grasses / 9003
5. Soil Map Symbol 63/C3H
6. Surname Ward
7. Date 08 mo 74 yr
8. Area –
9. County 075
10. Location Sec. 26, T. 3S, R. 45E
11. Photo No. ———
12. Writeup No. 15
13. File No. ———
14. Parent Rock Colluvium & interbedded siltstone and shale
15. Formation Name Fort Union
16. Surface Conditions (percent) Stone – 0 Rock – 0
17. Land Conditions Alkaline low to mod Saline mod to high Water table > 5'
18. Landform Colluvial slope in rolling hills
19. Slope (percent) 8/15 ☒ Single ☐ Complex
20. Aspect W
21. Elevation 3210
22. Present Erosion Type SSF — Class 3
23. Hydrologic Group –
24. Precipitation (in) 13.7 1st , 2nd , 3rd , 4th
25. Temperature — Air — Soil
26. Frost-free Days 130 > 28°
27. Drainage Class poorly drained
28. Infiltration mod. to slow
29. Percolation slow
30. ERD 7 in
31. AWC 2.8 in

32. HORIZON	33. THICKNESS	34. COLOR DRY MOIST MATRIX	MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH) 1-5 CaCl2	42. BOUNDARY
A1	0-5	D-(10YR 7/2) m-(10YR 5/2)		Lt SiCL	massive	D Hard m v firm		many		+ 8.1 7.6	clear wavy
C1cs	5-14	D (10YR 6/3) m (10YR 5/2)	gyp crystals	Lt C	coarse granular	D Hard m v firm		many to few		N 7.6 7.5	diffuse
C2cs	14-24	D-(10YR 7/1) m-(10YR 5/2)	gyp crystals	Lt C	Raw clay shale	D m v firm		few to none		N 8.0 8.0	

Silt stone found at 14" about 200' west (10YR 7/6) Big sage has been killed by spraying. Fair to good cover of side-oats grama, bluegrama, western wheat, green needle and prairie june grass. Broomweed, cheatgrass and yucca are common in the area. Some very small erosion terracing or soil slippage was noted. Salt tolerant sedge in small quantities encroach in the eroded spots.

Alkalinity and Salinity starts at 5"

(Instructions inside back cover)

Form 7310–9 (December 1970)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION–SOIL DESCRIPTION

1. State 25
2. District 02
3. Planning Unit L2
4. Vegetation–Soil Unit [illegible] grasses , 9005
5. Soil Map Symbol 05/ATM
6. Surname Ward
7. Date 22 mo 74 yr
8. Area —
9. County 075
10. Location Sec. 26, T. 3S, R. 45E
11. Photo No. ----------
12. Writeup No. 16
13. File No. ------
14. Parent Rock Interbedded siltstone and shale
15. Formation Name Fort Union
16. Surface Conditions *(percent)* Stone – 0 Rock – 0
17. Land Conditions Alkaline Non Saline Non Water table
18. Landform Tabular divide
19. Slope *(percent)* 0/2 ☒ Single ☐ Complex
20. Aspect N
21. Elevation 3200'
22. Present Erosion Type SSF – – – Class L
23. Hydrologic Group –
24. Precipitation *(in)* 13.7 1st , 2nd , 3rd , 4th
25. Temperature – – Air – – Soil
26. Frost-free Days 130 > 28°
27. Drainage Class Mod. well drained
28. Infiltration Moderate
29. Percolation Moderate
30. ERD 7 in
31. AWC 2.1 in

32. HORIZON	33. THICKNESS inches	34. COLOR DRY MOIST MATRIX	34. COLOR DRY MOIST MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH) 1-5 CaCl2	42. BOUNDARY
A1	0-2	D (10YR 7/3) m (10YR 6/4)		FSL	platy	D- soft m- friable		many		8.0 7.6	clear smooth
AC	2-8	D- (10YR 7/3) m- (10YR 6/4)		FSl	med & fine sub ang blky	D- sli hard m- friable		many			abrupt
C1	8-16	D (10YR 8/4) m (10YR 8/3)	(10YR 7/8) (10YR 7/6)	lt FSCL	coarse platy	D sli hard m firm		many to com		8.4 7.7	abrupt
C2	16-21	D (10YR 8/2) m (10YR 8/3)	(10YR 8/2 (10YR 8/6)	VFSL	consolidated layered sand st						

A good cover of native vegetation includes sideoats grama, Slender wheat, Blue grama, Prairie june grass, scattered big sage and a [illegible] Ponderosa Pine. Lenticular hard sandstone occurs locally. The 8-16 inch horizon consists of layered highly weathered raw soil from fine sandy shale. The 16-21 inch layer consists of layered fine sandstone

(Instructions inside back cover)

Form 7310–9 (December 1970)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION–SOIL DESCRIPTION

1. State 25
2. District 02
3. Planning Unit 12
4. Vegetation–Soil Unit Pine-grass 9003
5. Soil Map Symbol 03 D3M
6. Surname Ward
7. Date 08 mo 74 yr
8. Area --
9. County 075
10. Location Sec. 26, T. 35, R. 45E
11. Photo No. ----------
12. Writeup No. L7
13. File No. ------
14. Parent Rock sandstone and inter-bedded siltstone and shale
15. Formation Name Fort Union
16. Surface Conditions (percent) Stone -*- Rock -*-
17. Land Conditions Alkaline Slight to mod (subsoil) Saline Non Water table > 5'
18. Landform Residual slope
19. Slope (percent) 8/30 ☐ Single ☒ Complex
20. Aspect NW
21. Elevation 3180'
22. Present Erosion Type SSF --- Class 3
23. Hydrologic Group -
24. Precipitation (in) 13.7 1st , 2nd , 3rd , 4th
25. Temperature -- Air -- Soil
26. Frost-free Days 130 > 28°
27. Drainage Class Well drained
28. Infiltration High
29. Percolation Mod to slow
30. ERD 9 in
31. AWC 4.5 in

32. HORIZON	33. THICKNESS	34. COLOR DRY MOIST MATRIX	MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH) 1-5 CaCl2	42. BOUNDARY
A1	0-6	D-(10YR 6/4) m-(10YR 4/4)		fSL	fine & med gran	D- soft m. friable		many		+++ 8.1 7.6	Clear wavy
AC	6-16	D-(10YR 8/4) m-(10YR 7/6)		SiL	fine sub-angblky	D- soft m. friable		many		+++ 8.3 7.7	Abrupt
C1	16-30	D (10YR 8/3) m(10YR 7/3)		SiL	weakly consolidated siltstone	D. m. friable		Com to few		+++ 8.5 8.0	
C2	30-36	D(10YR 8/1) m(10YR 7/1)		SiCL	consolidated silty shale	m firm		few to none		N 8.4 8.1	

*** The upper slopes immediately below the ledge is strewn with blocks of large massive sandstone of 3 feet and more. Sandstone flags are numerous also but diminish in number and size. Mid to lower slopes have few flags but, sandstone outcrops from knobs.

A fair to good cover of native vegetation is composed of Ponderosa Pine, sideoats grama, slender wheat and prairie june. Many small unstable hills with loose rock are actively eroding but the amount is small except when torrential rains occur.

Alkalinity starts at 16 inches.

(Instructions inside back cover)

Form 7310-9 (December 1970)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION–SOIL DESCRIPTION

1. State 25
2. District 02
3. Planning Unit 12
4. Vegetation–Soil Unit Mixed grasses, 9009
5. Soil Map Symbol Bg / ATM
6. Surname Ward
7. Date 08 mo 74 yr
8. Area --
9. County 075
10. Location Sec. 26, T. 35, R. 45E
11. Photo No. ----------
12. Writeup No. 18
13. File No. ------
14. Parent Rock Colluvium, alluvium a Interbedded shale
15. Formation Name Fort Union
16. Surface Conditions *(percent)* Stone – 0 Rock – 0
17. Land Conditions Alkaline High Saline High Water table > 10'
18. Landform Colluvial slope
19. Slope *(percent)* 0/2 ☒ Single ☐ Complex
20. Aspect N
21. Elevation 3150
22. Present Erosion Type SSF --- Class L
23. Hydrologic Group -
24. Precipitation *(in)* 13.7 1st , 2nd , 3rd , 4th
25. Temperature -- Air -- Soil
26. Frost-free Days 130 > 28°
27. Drainage Class Poorly drained
28. Infiltration very slow
29. Percolation very slow
30. ERD 0 in
31. AWC --.- in

32. HORIZON	33. THICKNESS	34. COLOR DRY MOIST MATRIX	MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH)	42. BOUNDARY
										1-5 CaCl2	
	0-12			Lt SiCL						+++ 8.1 8.2	
	12-24			Lt SiCL						+++ 8.4 8.5	
	24-36			Lt SiCL						+++ 8.7 8.5	
	36-48			Lt SiCL						+++ 8.7 8.5	
	48-64			Lt SiCL						+++ 8.8 86	

The field notes on this profile were lost. It was dug in an active slick spot. I only remember the soil material was very plastic and very sticky. This condition exceeded the normal plasticity of a silty clay loam.

(Instructions inside back cover)

Form 7310–9 (December 1970)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION–SOIL DESCRIPTION

1. State 25
2. District 02
3. Planning Unit 12
4. Vegetation–Soil Unit mixed grasses, 9005
5. Soil Map Symbol 65/AIM
6. Surname Ward
7. Date 07 mo 24 yr
8. Area --
9. County 075
10. Location Sec. 34, T. 3S, R. 45E
11. Photo No. ----------
12. Writeup No. 1
13. File No. ------
14. Parent Rock Sandstone/Silty Shale
15. Formation Name Fort Union
16. Surface Conditions (percent) Stone – 0 Rock – 0
17. Land Conditions Alkaline Non Saline Non Water table > 5'
18. Landform Tabular divide
19. Slope (percent) 0/3 ☒ Single ☐ Complex
20. Aspect N
21. Elevation 3260
22. Present Erosion Type SSF --- Class 1
23. Hydrologic Group -
24. Precipitation (in) 13.7 1st, 2nd, 3rd, 4th
25. Temperature -- Air -- Soil
26. Frost-free Days 130 > 28°
27. Drainage Class Mod well drained
28. Infiltration High
29. Percolation mod to high
30. ERD 10 in
31. AWC 4.6 in

32. HORIZON	33. THICKNESS	34. COLOR DRY / MOIST MATRIX	MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH) 1-5 CaCl2	42. BOUNDARY
A1	0-2	D-(2.5y 7/2) m-(2.5y 5/4)		SiL (VFSL)	fine granular	D soft m-friable	None	Many		+++ 72 6.9	gradual
AC	2-8	D-(2.5y 5/4) m-(2.5y 4/4)		SiL	med & fine Granular	D-soft m. friable	None	many		++ 8.3 7.5	Abrupt
C1CA	8-13	D-(2.5y 7/4) m(2.5y 5/4)		SiL	Mod to fine wk Subang Blocky	D. Sli Hard m. friable		many		++ 9.0 7.9	Abrupt
C2	13-26	D-(2.5y 4/3) m-(2.5y 5/4)		SiL	Weak massive	D- m-		common		+	Abrupt
C3	26+					Hard sandstone					

A good cover of native vegetation consists of green needle, needle and thread, prairie june and blue grama grass, scattered big sage and ponderosa pine around the edge of the area. Lenticular hard sandstone occurs at or near the surface locally. Percent of area with this sandstone is small

(Instructions inside back cover)

Form 7310-9 (December 1970)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION–SOIL DESCRIPTION

1. State 25
2. District 02
3. Planning Unit L2
4. Vegetation–Soil Unit Mixed grasses, 9003
5. Soil Map Symbol 02/B2N
6. Surname Ward
7. Date 6 7 mo 24 yr
8. Area --
9. County 075
10. Location Sec. 34, T. 3S, R. 45E
11. Photo No. ----------
12. Writeup No. 2
13. File No. ------
14. Parent Rock Interbedded siltstone + shale local colluvium
15. Formation Name Fort Union
16. Surface Conditions *(percent)* Stone – 0 Rock – 0
17. Land Conditions Alkaline Mod to high (subsoil) Saline Mod to high (subsoil) Water table > 6'
18. Landform Undulating Tabular divide
19. Slope *(percent)* 2-8 ☐ Single ☒ Complex
20. Aspect E
21. Elevation 3260'
22. Present Erosion Type SSF – – – Class 2
23. Hydrologic Group –
24. Precipitation *(in)* 13.7 1st, 2nd, 3rd, 4th
25. Temperature – – Air – – Soil
26. Frost-free Days 130 > 28°
27. Drainage Class Mod well drained
28. Infiltration High
29. Percolation very slow
30. ERD 9 in
31. AWC 2.7 in

32. HORIZON	33. THICKNESS	34. COLOR DRY / MOIST: MATRIX	34. COLOR DRY / MOIST: MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH) 1-5	41. REACTION (pH) CaCl2	42. BOUNDARY
A1	0-2	D-(10YR 5/2) m-(10YR 4/3)		L	fine granular	D-soft m-friable	None	many	None	8.1	7.3	clear wavy
AC	2-6	D-(10YR 5/3) m-(10YR 3/3)		CL	wk Prismatic to fine Ang blky	D-Sl. Hard m-friable	None	many	none	8.2	7.4	gradual
C1	6-10	D-(10YR 7/1) m-(10YR 6/3)		SiCL	weak Prismatic	D-sli Hard m-friable	None	Many	None	9.0	7.7	clear
C2	10-24	D-(10YR 6/2) m-(10YR 5/2)	threads and pockets of lime	C	Med + Co blocky	D-Hard m-firm		many	none	9.6	8.2	Abrupt
C3	24-32	D-(10YR 7/1) m-(10YR 5/2)	D (10YR 8/2) + m (10YR 3/2) lime	MC	Massive	D-Very Hard m-very firm		Com	None	9.1	8.6	
C4	32-52	D-(2.5Y 6/2) m-(2.5Y 5/2)		LtC	Weak Ang. Blocky	D-Hard m-firm		few to none	None	8.6	8.2	
C5Cs	52-60	D-(2.5Y N6/) m-(2.5Y N4/)	Iron stains between layers	MC	Consolidated	D-Hard m-very firm			None	8.8	8.2	
C6Cs	60-64	D-(2.5Y N6/ m-(2.5Y N4/)		MC	shale	D-Hard m-very firm			None	9.5	8.3	

Sampled with a Hydraulic Core machine

A good cover of native vegetation consists of green needle, needle and thread, prairie june, western wheat and slender wheatgrass. A few big sage dot the area

Salinity and Alkalinity starts at 24"

(Instructions inside back cover)

Form 7310–9 (December 1970)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION–SOIL DESCRIPTION

1. State 25
2. District 02
3. Planning Unit 12
4. Vegetation–Soil Unit Mudgrasse - 1 - 9005
5. Soil Map Symbol $\frac{05}{AtM}$
6. Surname Ward
7. Date 67 mo 74 yr
8. Area --
9. County 019
10. Location Sec. 34, T. 3S, R. 45E
11. Photo No. ----------
12. Writeup No. 3
13. File No. ------
14. Parent Rock Interbedded sandstone siltstone and Shale
15. Formation Name Fort Union
16. Surface Conditions (percent) Stone – 0 Rock – 0
17. Land Conditions Alkaline Nontoniod (subsoil) Saline Mod to high (subsoil) Water table > 11.5'
18. Landform Tabular divide
19. Slope (percent) 0/3 ☐ Single ☒ Complex
20. Aspect S
21. Elevation 3265'
22. Present Erosion Type SSF --- Class 1
23. Hydrologic Group -
24. Precipitation (in) 13.7 1st , 2nd , 3rd , 4th
25. Temperature -- Air -- Soil
26. Frost-free Days 130 > 28°
27. Drainage Class Mod well drained
28. Infiltration High
29. Percolation Mod to high
30. ERD 12 in
31. AWC 5.1 in

32. HORIZON	33. THICKNESS	34. COLOR DRY MOIST MATRIX	MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH) 1-5 CaCl2	42. BOUNDARY
A1	0-3	D-(10YR 7/2) m-(10YR 6/3)		VFSL	fine granular	D-soft m-friable	None	many		++ 8.6 7.5	Clear
AC	3-12	D-(10YR 7/4) m-(10YR 6/4)		FSL	weak massive	D-soft m-friable		many		++ 8.6 7.6	gradual
C1CA	12-28	D-(10YR 7/4) m-(10YR 5/4)		Lt. fSL	weak massive	D-soft m-friable		many		+++ 8.7 7.8	Abrupt
C2CA	28-31	D-(2.5Y 8/4) m-(2.5Y 7/6)		Lt SiL	Consolidated Shale	D-soft m-friable		Many to com.		+++	
C3	31-39	D (10YR 7/6) m-(10YR 6/6)		SiL	Horizontal layering	D-soft m-friable		few to none		++ 8.6 8.0	
C4	39-51	D-(10YR 8/2) m-(10YR 6/3)		LS		D-soft m-V friable				++ 8.6 8.2	
C5	51-62	D-(10YR 8/4) m-(10YR 6/4)		SiCL		D-Hard m-firm				++	
C6CS	62-65	D-(2.5Y N8/) m-(2.5Y N6/)	gypsum crystals	C		D-Hard m-firm				N	
C7	65-70	D-(2.5Y N8/ M-(2.5Y N5/)	lignite	CL		D-Sli hard m friable				N 6.0	
C8	70-76	D-(2.5Y N7/) m-(2.5Y N4/)		C		D-Hard m-firm				N 6.2	
C9	76-80	D (2.5Y N7/ m-(2.5Y N3/)	lignite & threads of (10YR 8/6)	CL		D-Sli Hard m friable				N 5.9	
C10	80-116	m (2.5Y N2/)	1" layer of lignite at 112-113"	C		D-Hard m-firm				N 8.1 7.9	
C11	116-118	D-(2.5Y 8/8) m-(2.5Y 7/8)		SiCL		D-Hard m-firm				N	
C12CS	118-140	D-(2.5Y N8/) m-(2.5Y N7/)	threads and small pockets of salts	C		D-Hard m-firm				N 6.7 6.7	
	140-146		Lignite mixed with shale	C		D-Hard m firm					

(Salinity starts at 31" and Alkalinity at 40")

See #1 for general description

(Instructions inside back cover)

Form 7310–9 (December 1970)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION-SOIL DESCRIPTION

1. State 25	2. District 02	3. Planning Unit 12	4. Vegetation-Soil Unit mixed grasses - 9002	5. Soil Map Symbol $\frac{02}{ATN}$	6. Surname Ward	7. Date 07 mo 74 yr
8. Area --	9. County 025	10. Location Sec. 34, T. 3S, R. 45E	11. Photo No.	12. Writeup No. 4	13. File No.	14. Parent Rock Interbedded siltstone shale and Colluvium

15. Formation Name: Fort Union

16. Surface Conditions (percent): Stone – 0 Rock – 0

17. Land Conditions: Alkaline Non Saline high (subsoil) Water table 7 5'

18. Landform: colluvial slopes in rolling hills

19. Slope (percent) 2/4 ☒ Single ☐ Complex

20. Aspect W

21. Elevation 3170'

22. Present Erosion: Type SSF — Class 1

23. Hydrologic Group –

24. Precipitation (in) 13.7 1st , 2nd , 3rd , 4th

25. Temperature: — Air — Soil

26. Frost-free: Days 130 > 28°

27. Drainage Class: Mod well drained

28. Infiltration: Moderate

29. Percolation: Mod to slow

30. ERD 12 in

31. AWC 8.3 in

32. HORIZON	33. THICKNESS	34. COLOR DRY/MOIST: MATRIX	34. COLOR: MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH) 1-5 CaCl₂	42. BOUNDARY
A1	0-8	D. (10YR 6/3) m. (10YR 4/3)		SiCL	fine greanuler	D - Soft m - friable	None	Many	None	W 8.3 7.6	Abrupt
B2T	8-16	D - (10YR 5/3) m. (10YR 3/2)		SiCL	Prismatic med. to P. Blky	D - Hard m - firm	patchy	many	none	+ 8.8 7.8	difuse
C1	16-30	D - (2.5Y 6/3) m - (2.5Y 4/3)		SiCL	st. Ang Blocky	D - Hard m - friable	None	many to few	none	++ 8.4 8.1	Abrupt
C2	30-42	D - (10YR 7/3) m - (10YR 5/6)		Hv. SiL.	massive consolidated shale	D - Hard m - friable		few		W 8.9 8.4	

A good stand of western wheat, prairie june and needle and thread grass covers the area. The soil and vegetation have stabilized with the climate. Immediately north of this profile is a large eroded shale area that is devoid of vegetation.

(Salinity starts at 16")

(Instructions inside back cover)

Form 7310-9 (December 1970)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION–SOIL DESCRIPTION

1. State 25
2. District 02
3. Planning Unit 12
4. Vegetation–Soil Unit mixed grassl, 9003
5. Soil Map Symbol 82/E4N
6. Surname Ward
7. Date 07 mo 24 yr
8. Area –
9. County 075
10. Location Sec. 34, T. 3S, R. 45E
11. Photo No. ----------
12. Writeup No. 5
13. File No. ------
14. Parent Rock Interbedded siltstone and shale
15. Formation Name Fort Union
16. Surface Conditions (percent) Stone – – Rock – –
17. Land Conditions Alkaline Non Saline High (Subsoil) Water table > 5'
18. Landform Residual slope in rolling hills
19. Slope (percent) 3/12 ☐ Single ☒ Complex
20. Aspect SW
21. Elevation 3195'
22. Present Erosion Type SSF – – – Class 4
23. Hydrologic Group –
24. Precipitation (in) 13.7 1st , 2nd , 3rd , 4th
25. Temperature – – Air – – Soil
26. Frost-free Days 130 28°
27. Drainage Class well drained
28. Infiltration High
29. Percolation slow
30. ERD 9 in
31. AWC 2.2 in

32. HORIZON	33. THICKNESS	34. COLOR DRY/MOIST MATRIX	MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH) 1-5 CaCl2	42. BOUNDARY
A1	0-6	D-(10YR 7/3) m-(10YR 4/4)		Lt SiCL	fine granular	D- soft m- friable	None	Many	None	+ 8.5 7.6	clear
AC	6-12	D-(10YR 7/3) m-(10YR 4/6)	D-(10YR 6/1) m-(10YR 4/1)	SiCL	Wk prismatic to mef blky	D Sli Hard m friable	none	many	None	++ 9.1 8.0	Abrupt
C1	12-27	D-(10YR 7/4) m-(10YR 4/6)		Lt SiCL	Massive	D- Hard m- firm	none	many to few	none	++ 8.5 8.0	Abrupt
C2	27-38	D-(10YR 7/4) m-(10YR 4/6)		SiC	Shale thin Horizontal bedding	D- Hard m- friable	none	few	none	N 8.4 8.1	
C3	38-48	D-(10YR 7/4) m-(10YR 5/6)		Stratified Lt SiCL/vfSL						N 8.7 8.1	

A fair to good stand of needle and thread, prairie june, and slender wheatgrass grows in combination with a scattered stand of big sage and ponderosa pine. Numerous forbes are found on the more shallow soil. Rill erosion is common. Some sandstone flags and an occasional large block of massive sandstone.
(Salinity starts at 12")

(Instructions inside back cover)

Form 7310-9 (December 1970)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION–SOIL DESCRIPTION

1. State 25	2. District 02	3. Planning Unit 12	4. Vegetation–Soil Unit Mixed grasses 2007	5. Soil Map Symbol ~~AIN~~ B7	6. Surname Ward	7. Date 1 mo 74 yr
8. Area –	9. County 075	10. Location Sec. 34, T. 3S, R. 45E	11. Photo No. –	12. Writeup No. 6	13. File No. –	14. Parent Rock Interbedded sandstone siltstone and shale

15. Formation Name: Fort Union
16. Surface Conditions (percent): Stone – 0 Rock – 0
17. Land Conditions: Alkaline high subsoil Saline high subsoil Water table > 5'
18. Landform: Tabular [illegible]
19. Slope (percent) 0/3 ☒ Single ☐ Complex
20. Aspect: NW
21. Elevation: 3183'
22. Present Erosion: Type SSF – – – Class 1
23. Hydrologic Group: –
24. Precipitation (in) 13.7 1st, 2nd, 3rd, 4th
25. Temperature – – Air – – Soil
26. Frost-free Days 130 28°
27. Drainage Class: Mod well drained
28. Infiltration: Moderate
29. Percolation: Mod [illegible]
30. ERD 16 in
31. AWC 9.0 in

32. HORIZON	33. THICKNESS	34. COLOR DRY MOIST MATRIX	MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH) 1-5 CaCl2	42. BOUNDARY
A1	0-2	D-(10YR 7/2) m-(10YR 6/4)		vfsl	platy	D- Soft m- friable	none	many			abrupt
B2t	2-8	D-(10YR 6/6) m-(10YR 4/4)		CL	med. Ang. blky	D. sli hard m. friable	thin [illegible]	many		7.2 7.0	clear
C1	8-18	D-(10YR 5/6) m-(10YR 4/4)		CL	Prismatic	D- sli hard m- friable	None	many		8.5 7.7	wavy
C2	18-34	D.(10YR 7/3) m-(10YR 6/2)		FSL	Massive	D sli hard m friable	–	many to few		9.2 7.9	abrupt
C3	34-40	D-(10YR 5/4) m-(10YR 4/2)		FSL		D- soft m friable		few to none		9.2 8.0	
C4CA	40-46	D.(10YR 6/3) m-(10YR 4/3)	Lime [illegible] Pea [illegible]	CL		D- m- friable				9.0 8.3	
C5CS	46-60	D (10YR 7/4) m-(10YR 5/6)	Pockets of Gypsum	SiCL		D- m- friable				8.8 8.3	

The north edge of a small tabular divide. Slick spots are moderately numerous here. However some of the slick spots are beginning to revegetate. The percentage of raw barren slick spots is about 5 to 10%. The fair stand of native vegetation consists of needle and thread, green needle, prairie june and blue gramagrass. Big sage has been sprayed and cheat grass and other forbs are common (Salinity and Alkalinity start at 40").

(Instructions inside back cover)

Form 7310–9 (December 1970)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION–SOIL DESCRIPTION

1. State 25
2. District 02
3. Planning Unit 12
4. Vegetation–Soil Unit Mixed grasses – 9003
5. Soil Map Symbol 03/B2N
6. Surname Ward
7. Date 07 mo 74 yr
8. Area –
9. County 075
10. Location Sec. 34, T. 3S, R. 45E
11. Photo No. ——
12. Writeup No. 1
13. File No. ——
14. Parent Rock Silty shale
15. Formation Name Fort Union
16. Surface Conditions (percent) Stone – 0 Rock – 0
17. Land Conditions Alkaline Mod (Subsoil) Saline High (Subsoil) Water table > 6'
18. Landform Residual slope in rolling hills
19. Slope (percent) 4/8 ☐ Single ☒ Complex
20. Aspect N
21. Elevation 3155'
22. Present Erosion Type SSF — Class 2
23. Hydrologic Group –
24. Precipitation (in) 13.7 1st, 2nd, 3rd, 4th
25. Temperature — Air — Soil
26. Frost-free Days 130 > 28°
27. Drainage Class Mod. well drained
28. Infiltration Moderate
29. Percolation Very slow
30. ERD 8 in
31. AWC 6.8 in

32. HORIZON	33. THICKNESS	34. COLOR DRY/MOIST MATRIX	34. COLOR MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH) 1-5 CaCl2	42. BOUNDARY
A1	0-6	D-(2.5Y 6/4) m-(2.5Y 5/4)		Lt SiCL	fine granular	D- soft m- friable	none	many	none	++ 8.7 7.8	clear
AC	6-10	D-(2.5Y 6/4) m-(2.5Y 5/4)		SiCL	Med & fine granular	D. Hard m. friable	none	many	none	++ 8.9 7.9	gradual
C1	10-20	D (2.5Y 6/3) m (2.5Y 4/4)		SiCL	wk Prismatic to Ang blky	D- m- friable	None	many to few	none	++ 8.8 8.1	abrupt
C2CA	20-34	D-(2.5Y 7/6) m-(2.5Y 6/6)		SiCL	fine Blocky	D m- friable	none	few to none	none	+++ 8.7 8.3	abrupt
C3CA	34-44	D-(2.5Y 8/2) m-(2.5Y 7/6)		SiL	Consolidated si shale	Hard in place breaks down easy				+++ 9.1 8.5	
C4CA	44-48	D-(2.5Y 7/2) m-(2.5Y 6/2)		SiCL	"	Med Hard in place				+++ 9.0 8.6	
C5CS	48-52	D-(2.5Y N8/) m. (2.5Y 7/2)		fSCL	"	Hard in place Pard breaks down part remains hard				+ 8.9 8.5	
C6CS	52-60	D-(2.5Y N8/) m-(2.5Y 6/6)		vfSCL	"	Hard in place Some parts break down easily				+ 8.8 8.5	
C7CS	60-64									N 8.9 8.4	

This residual slope is typical of many similar slopes that occur in this section. Here NE slope the surface relief is broken by sandstone erratics with localized sandy soil and little bluestem grass across the natural drain east the slope there is quite similar but does not receive aeolian material and [illegible] slope [illegible] (Salinity and alkalinity starts at 10 to 20")

(Instructions inside back cover)

Form 7310–9 (December 1970)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION–SOIL DESCRIPTION

1. State 25
2. District 02
3. Planning Unit L2
4. Vegetation–Soil Unit mixed grasses - 9003
5. Soil Map Symbol $\frac{03}{C3N}$
6. Surname Ward
7. Date 08 mo 27 yr
8. Area –
9. County 075
10. Location Sec. 24, T. 3S, R. 45E
11. Photo No. ----------
12. Writeup No. 8
13. File No. ------
14. Parent Rock Sandstone
15. Formation Name Fort Union
16. Surface Conditions *(percent)* Stone – – Rock – –
17. Land Conditions Alkaline Non Saline Non Water table > 6'
18. Landform Rolling hills
19. Slope *(percent)* 7-12 ☐ Single ☒ Complex
20. Aspect S
21. Elevation 3165'
22. Present Erosion Type SSF – – – Class 3
23. Hydrologic Group –
24. Precipitation *(in)* 13.7 1st , 2nd , 3rd , 4th
25. Temperature – – Air – – Soil
26. Frost-free Days 130 28°
27. Drainage Class Well drained
28. Infiltration high
29. Percolation high
30. ERD – in
31. AWC – L.L in

32. HORIZON	33. THICKNESS	34. COLOR DRY / MOIST: MATRIX	34. MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH) 1-5 CaCl₂	42. BOUNDARY
A1	0-6	D-(2.5Y 7/3) m.(2.5Y 6/3)		SiL	fine granular	D - soft- m - friable	None	many	None	++	Abrupt
C1	6-22	D-(2.5Y 7/2) m-(2.5Y 6/3)		FSL	Consolidated Sandstone	D. Soft m. friable out		many to few		N	gradual
C2	22-24	D (2.5Y 7/3) m (2.5Y 6/4)		SL	"	Balance of profile		few		W	Gradual
C3	24-40	D-(2.5Y 7/3) m-(2.5Y 6/4)		LtVFSL	"	horizontally bedded		few to none		W 9.2 8.2	Abrupt
C4	40-42	D (2.5Y 7/6) m (2.5Y 5/4)		FSL	"	Sandstone				W	
C5	42-54	D-(2.5Y 7/6 m-(2.5Y 6/8)		Lt. FSL	"	that is hard in place				W 9.3 8.1	
C6	56-60	D-(2.5Y 6/2) m-(2.5Y 5/2)		SL	"	breaks down and is				W 9.4 8.2	
C7	60-64	D-(2.5Y N8/) m-(2.5Y N7/		LtVFSL	"	friable				N	

This profile represents a small area of shallow residual soil on a slope. The top of a knob has stoney alluvium and local alluvium is along a small natural drain. Vegetative cover consists of a good stand of mixed grasses. Soils and shallow geologic material are good here. Average depth of soil is about 18-30"

8/27/74

(Instructions inside back cover)

Form 7310-9 (December 1970)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION–SOIL DESCRIPTION

1. State 25	2. District 02	3. Planning Unit 12	4. Vegetation–Soil Unit Mixed grasses 9003	5. Soil Map Symbol 83 ~~CAN~~	6. Surname Ward	7. Date 07 mo 74 yr
8. Area --	9. County 075	10. Location Sec. 34, T. 3S, R. 45E	11. Photo No.	12. Writeup No. 9	13. File No.	14. Parent Rock Interbedded sandstone siltstone and shale
15. Formation Name Fort Union	16. Surface Conditions (percent) Stone – 0 Rock – 0	17. Land Conditions Alkaline Non Saline None Water table > 4'				18. Landform Residual slope in rolling hills
19. Slope (percent) 4/15 ☐ Single ☒ Complex	20. Aspect E	21. Elevation 3160'	22. Present Erosion Type SSF Class 2			23. Hydrologic Group –
24. Precipitation (in) 13.7 1st, 2nd, 3rd, 4th	25. Temperature Air Soil	26. Frost-free Days 130, 28°	27. Drainage Class Modwell drained	28. Infiltration mod to high	29. Percolation mod to slow	30. ERD 8 in
31. AWC 2.6 in						

32. HORIZON	33. THICKNESS	34. COLOR DRY MOIST		35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH) 1-5 CaCl2	42. BOUNDARY
		MATRIX	MOTTLING								
A1	0-6	D- (2.5Y 7/6) m- (2.5Y 6/6)		L	fine granular	D- soft m- friable	None	many	None	++	wavy
AC	6-15	D- (2.5Y 7/6) m- (2.5Y 6/4)		L	Fine granular	D- soft m- friable	None	many		++	wavy
C1	15-27	D- (2.5Y 7/3) m- (2.5Y 6/2)	yellow cast	HvfSL	Consolidated sandstone	D- Sl. hard m- friable	None	many to		++	abrupt
C2	27-42	D- (2.5Y 7/3) m- (2.5Y 6/4)		SiCL	"	D- m- friable [illegible]		few		+	
C3	42-48	D- (2.5Y 7/4) m- (2.5Y 6/4)		Hv.fSL	"	D- m- friable [illegible]				+	

The stand and amount of vegetative cover is quite variable. Side oats grama, and slender wheat grow best on the lower slopes among the pine. Western wheat and prairie june grass and scattered sedges and forbs grow on the very shallow (< 6") soils over silty and clayey shale. The shales are often saline and/or alkaline

(Instructions inside back cover)

Form 7310–9 (December 1970)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION–SOIL DESCRIPTION

1. State 25
2. District 02
3. Planning Unit 12
4. Vegetation–Soil Unit Mixed grasses 2003
5. Soil Map Symbol 03/C3H
6. Surname Ward
7. Date 07 mo 74 yr
8. Area –
9. County 075
10. Location Sec. 34, T. 3S, R. 45E
11. Photo No. ----------
12. Writeup No. 10
13. File No. ------
14. Parent Rock Interbedded siltstone and shale
15. Formation Name Fort Union
16. Surface Conditions (percent) Stone 1/ Rock 1/
17. Land Conditions Alkaline Non Saline high (subsoil) Water table > 6'
18. Landform Residual slope in rolling hills
19. Slope (percent) 4/12 ☐ Single ☒ Complex
20. Aspect S
21. Elevation 3210'
22. Present Erosion Type SSF --- Class 3
23. Hydrologic Group –
24. Precipitation (in) 13.7 1st , 2nd , 3rd , 4th
25. Temperature -- Air -- Soil
26. Frost-free Days 130 > 28°
27. Drainage Class Mod well drained
28. Infiltration High
29. Percolation Mod to very slow
30. ERD 6 in
31. AWC 1.6 in

32. HORIZON	33. THICKNESS	34. COLOR DRY MOIST MATRIX	MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH) 1-5 CaCl₂	42. BOUNDARY
A1	0-3	D-(2.5Y 6/4) m-(2.5Y 5/6)		SiCL	fine granular	D-Soft m-friable	None	Many	None	++ 8.5 7.8	Clear
AC	3-10	D- m-(2.5Y 5/4)		Lt. C	Med sub-angular Blocky	D-sl. Hard m-Friable	None	many	None	++ 8.0 7.9	gradual
C1CS	10-14	D- m-(2.5Y 6/6)	Shale flakes (2.5Y 4/4) gyp.	Lt C		D-Hard m-friable	None	many to few	none	++ 8.0 7.9	gradual
C2CS	14-24	D- m-(2.5YR 5/6)	Shale flakes (2.5YR 4/4) gyp	M C	fine Ang blky	D-Hard m-firm		few		+ 8.1 7.9	Abrupt
C3CS	24-34	D- m-(2.5Y 4/4)	Pockets of gyp.	HC	consolidated layered shale	D-Hard m-very firm		few to none		+ 8.1 8.0	Abrupt
C4CS	34-42	D- m-(2.5Y N2/)			Lignite	D- m-				N	Abrupt
C5CS	42-46	D- m-(2.5Y N4/)		HC	consolidated layered shale	D-Hard m-very firm				N 6.7 6.2	Abrupt
C6	46-49	D- m-(2.5Y N2/)			Lignite	D- m-				N	Abrupt
C7	49-58	D- m-(2.5Y 5/2)		HC	Consolidated layered shale	D-Hard m-very firm				N 6.6 6.4	gradual
C8	58-64	D- m-(2.5Y N5/)		MC	Consolidated layered shale					N	

(Salinity starts at 24")

1/ Rock and stone are localized. Large massive lenticular sandstone range up to 30' X 50' X 2-3' thick. Rock and stone is not a problem over most of the area. The stand and cover of mixed grasses are quite variable depending on depth and quality of soil. Salt sedge predominates on the clayey ridges.

(Instructions inside back cover)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION–SOIL DESCRIPTION

1. State 25
2. District 02
3. Planning Unit 12
4. Vegetation–Soil Unit Mixedgrassland, 9003
5. Soil Map Symbol 03 / B2N
6. Surname Ward
7. Date 02 mo 74 yr
8. Area –
9. County 075
10. Location Sec. 34, T. 1S, R. 45E
11. Photo No. ----------
12. Writeup No. 1L
13. File No. ------
14. Parent Rock Silty Shale
15. Formation Name Fort Union
16. Surface Conditions (percent) Stone – 0 Rock – 0
17. Land Conditions Alkaline Non Saline mod 1/ (subsoil) Water table 76'
18. Landform Ridge divide in rolling hills
19. Slope (percent) 3-6 ☒ Single ☐ Complex
20. Aspect NE
21. Elevation 3210'
22. Present Erosion Type SSF --- Class 2
23. Hydrologic Group –
24. Precipitation (in) 13.7 1st , 2nd , 3rd , 4th
25. Temperature -- Air -- Soil
26. Frost-free 130 Days ---> 28°
27. Drainage Class Mod well drained
28. Infiltration Mod high
29. Percolation Mod to slow
30. ERD 10 in
31. AWC 6.6 in

32. HORIZON	33. THICKNESS	34. COLOR DRY MOIST MATRIX	34. COLOR MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH) 1-5 CaCl2	42. BOUNDARY
A1	0-6	D-(10YR 7/1) m-(10YR 4/1)		CL	fine + med granular	D- Sli Hard m- Friable	None	many		N 8.2 7.4	clear
C1ca	6-20	D- m-(2.5YR 6/2)	Lime on ped faces	SiCL	med ang. blky	D- Hard m- Sli firm	None	many		+++ 8.6 7.7	gradual
C2	20-33	D- m-(2.5Y 6/2)	D- m-(10YR 6/6)	Lt. SiC	fine + med blky	D- m- friable		many to com		++ 8.2 7.9	abrupt
C3	33-36	D- m-(10YR 5/8)		Lt SiCL	consolidated shale	D- m- firm		few		N 8.3 7.8	
C4	36-40	D (10YR 7/1) m-(10YR 6/3)		SiCL	"	D- m- firm		few to none		N	
C5	40-48	D- m-(10YR 6/2)	some lignite & (10YR 8/6)	Lt C	"	D- m- firm		none	Hard shale flakes	N 8.1 7.8	
C6	48-50	D m-(2.5Y N2/)			fractured lignite	D- m-				N	
C7	50-58	D- m-(10YR 5/2)	(10YR 5/4)	LtC	consolidated shale	D- m-			Soft shale flakes	N 6.1 6.7	
C8	58-64	D- m-(10YR 4/1)		LtC	"	D- m-			Some Hard Shale flakes	N 6.4 5.8	

1/ A slightly acid condition exists in the shale where lignite is inter bedded. This condition occurs from 50 to 64 inches. A good stand of slender wheat, green needle, needle and thread, prairie june and blue grama covers this small area. Surrounding slopes have many shale exposures and very shallow soils.

(Instructions inside back cover)

Form 7310–9 (December 1970)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION–SOIL DESCRIPTION

1. State 25
2. District 02
3. Planning Unit L2
4. Vegetation–Soil Unit mixed grasses 9006
5. Soil Map Symbol 06 BZN
6. Surname Ward
7. Date 02 mo 74 yr
8. Area --
9. County 075
10. Location Sec. 34, T. 3S, R. 45E
11. Photo No. ----------
12. Writeup No. 12
13. File No. -------
14. Parent Rock Alluvium, Colluvium of silty to clayey shale
15. Formation Name Fort Union
16. Surface Conditions (percent) Stone – 0 Rock – 0
17. Land Conditions Alkaline Non Saline mod. (subsoil) Water table > 5'
18. Landform Alluvial fan and colluvia foot slope in rolling hills
19. Slope (percent) 3/8 ☐ Single ☒ Complex
20. Aspect N
21. Elevation 3180'
22. Present Erosion Type SSF --- Class 2
23. Hydrologic Group -
24. Precipitation (in) 13.7 1st , 2nd , 3rd , 4th
25. Temperature -- Air -- Soil
26. Frost-free Days 130 > 28°
27. Drainage Class well drained
28. Infiltration mod to slow
29. Percolation mod to slow
30. ERD 10 in
31. AWC 10.2 in

32. HORIZON	33. THICKNESS	34. COLOR DRY / MOIST MATRIX	MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH) 1-5 lime CaCl2	42. BOUNDARY
A1	0-2	D-(10YR 7/2) m-(10YR 4/2)		CL	fine granular	D- soft m- friable	None	many	None	W	Abrupt
B2t	2-4	D-(10YR 7/2) m-(10YR 4/2)		CL	Strong med ang. Blky to fine ABlk.	D Hard m. very firm	few patchy	many	None	N 78 7.3	diffuse
B3	4-14	D-(10YR 5/3) m.(10YR 4/2)		Lt C	St. prismatic to med Blky	D- Hard m- sli. firm		many		W 8.2 7.6	diffuse
C1	14-21	D-(10YR 6/3) m-(10YR 5/2)	very thin threads of lime	Lt C	St. prismatic to med Ang blky	D- Hard m- friable		many		++ 8.6 7.7	abrupt
C2	21-30	D-(10YR 6/3) m.(10YR 5/2)	thin threads of lime	Lt C	massive	D- m- Sli. firm		com.		++ 8.7 7.9	
C3	30-40	D-(10YR 6/4) m-(10YR 5/2)	thin threads of lime sli gyp.	Lt C		D- Hard m friable		few		++ 8.4 8.0	
C4	40-50	D-(10YR 5/3) m-(10YR 4/4)	threads of lime some gyp	Lt C		D- Hard m. friable		few to none		H 8.3 8.0	
C5	50-60	D-(10YR 5/3) m-(10YR 4/4)	very thin threads of lime.	Lt C		D- Sli. Hard m- friable		none		+ 8.3 7.9	
			Shards of bright orange siltstone								

A good stand of western wheat, green needle and prairie june grass form a dense cover over most of the area. Scattered big sage and pine dot the area. Adjacent steep slopes that rise to the tabular divide are locally strewn with many sandstone flags, and bluestem becomes the dominant grass

(Salinity starts at 30")

(Instructions inside back cover)

Form 7310–9 (December 1970)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION–SOIL DESCRIPTION

1. State 25
2. District 02
3. Planning Unit 12
4. Vegetation–Soil Unit Pine mixedgrass / 9003
5. Soil Map Symbol 03 EZM
6. Surname Ward
7. Date 07 mo 74 yr
8. Area –
9. County 075
10. Location Sec. 34, T. 3S, R. 45E
11. Photo No. ----------
12. Writeup No. L3
13. File No. ------
14. Parent Rock Colluvium and interbedded siltstone
15. Formation Name Fort Union
16. Surface Conditions (percent) Stone – 0 Rock – 0
17. Land Conditions Alkaline Non Saline NON Water table 75'
18. Landform Residual slope in rolling hills
19. Slope (percent) 8/25 ☒ Single ☐ Complex
20. Aspect N
21. Elevation 3190'
22. Present Erosion Type SSF --- Class 2
23. Hydrologic Group
24. Precipitation (in) 13.7 1st , 2nd , 3rd , 4th
25. Temperature -- Air -- Soil
26. Frost-free 130 Days ---> 28°
27. Drainage Class Mod well drained
28. Infiltration High
29. Percolation Moderate
30. ERD 9 in
31. AWC 3.3 in

32. HORIZON	33. THICKNESS	34. COLOR DRY MOIST MATRIX	MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH) 1-5' CaCl2	42. BOUNDARY
A1	0-5	D-(10YR 5/6) m-(10YR 4/4)		Lt. CL	med and fine granular	D- soft m- friable	None	many	None	N 8.1 7.6	clear
AC	5-9	D-(10YR 6/4) m-(10YR 5/2)	thin threads slight lime on peds	L	Weak med, ang blky. breaks to fine gran.	D- soft m- friable	None	many	none	++ 8.3 7.8	gradual
C1	9-16	D-(10YR 7/3) m-(10YR 6/3)	Slight lime on ped faces.	Si L	Weak sub ang blky breaks to med. gran.	D- soft m- friable	None	Many	None	++ 8.6 7.8	abrupt
C2	16-22	D-(2.5YR 5/4) m-(2.5Y 6/4)		Si L	Weathered thin layered siltstone	D- m- friable		Many		++ 8.8 7.9	
C3	22-25	D-(2.5YR 5/4) m. (2.5Y 6/4)	thin lime on ped faces	Lt Si CL	Consolidated siltstone many fragments	D- m- friable			4	++	
C4	25-31	D- (10YR 6/3) m-(10YR 5/6)		Si L		D- m- friable			Hard siltstone	+ 8.9 7.9	
C5	31-44	D-(2.5Y 7/3) m-(2.5Y 6/4)		Hv. SiL	"	D- m- friable				W 8.8 8.0	
C6	44-56	D-(2.5Y 7/3 m-(2.5Y 6/4)		SiCL	"	D m- friable				N 8.7 8.2	
C7	56-60	D- (2.5Y 7/8) m-(2.5Y 6/6			"	D m friable				W	

The good stand and cover of native vegetation in this area includes sideoats grama, green needle, slender wheat and prairie june grass. Pine of juniper and big sage comprise the woody plants. Soils are very shallow 4-6" on the steeper and more exposed sw facing slopes.

(Instructions inside back cover)

Form 7310–9 (December 1970)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION–SOIL DESCRIPTION

1. State 25
2. District 02
3. Planning Unit 12
4. Vegetation–Soil Unit mixed grasses 9004
5. Soil Map Symbol 04 / BZM
6. Surname Ward
7. Date -- mo -- yr
8. Area --
9. County 075
10. Location Sec. 34, T. 3S, R. 45E
11. Photo No. ----
12. Writeup No. 14
13. File No. ----
14. Parent Rock Alluvium
15. Formation Name Fort Union
16. Surface Conditions (percent) Stone – 0 Rock – 0
17. Land Conditions Alkaline Non Saline Non Water table 75'
18. Landform small tributary alluvial terrace
19. Slope (percent) 2-8 ☐ Single ☒ Complex
20. Aspect NW
21. Elevation 3165'
22. Present Erosion Type SSF – – – Class 2
23. Hydrologic Group –
24. Precipitation (in) 13.7 1st , 2nd , 3rd , 4th
25. Temperature – – Air – – Soil
26. Frost-free Days 130 > 28°
27. Drainage Class Very well drained
28. Infiltration high
29. Percolation high to mod
30. ERD 20 in
31. AWC 10.5 in

32. HORIZON	33. THICKNESS	34. COLOR DRY / MOIST: MATRIX	MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH) 1-5 CaCl2	42. BOUNDARY
A1	0-4	D-(10YR 6/3) m-(10YR 4/2)		L	fine granular	D- soft m- friable	None	many		+ 8.4 7.8	Clear
AC	4-11	D-(10YR 6/2) m-(10YR 4/4)	very light lime showing angels	L	Wk prismatic + f+m gran	D- soft m- friable	None	Many		++ 8.5 7.6	clear wavy
C1	11-16	D-(10YR 6/3) m(10YR 4/2)		L	Prismatic - to med ang blky	D- Sl. Hard m- friable	None	many to few		N 8.4 7.6	diffuse
C2CA	16-24	D-(10YR 7/3) m-(10YR 6/4)	threads and sml. pockets of lime	vfSL	Wk. Prismatic to f+m blky	D- Sl. Hard m- friable	None	few		+++ 8.6 7.8	Abrupt
C3CA	24-30	D-(10YR 7/3) m-(10YR 6/3)	threads and soft pockets of lime	SiL	weak ? massive	D- m- friable	None	few		+++ 8.7 7.9	
C4CA	30-52	D-(10YR 7/4) m-(10YR 6/4)	Lime on rock and ped faces	SiL	weak ? massive	D- m. friable	None	few to none	Numerous	+++ 9.0 7.8	

This soil appears to have been derived in part from old alluvium eroded from the uplands, mixed with some local alluvium and redeposited. It supports a good cover of green needle, western wheat, slender wheat and blue grama. Big sage occur at random.

(Instructions inside back cover)

Form 7310–9 (December 1970)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION–SOIL DESCRIPTION

1. State 25
2. District 02
3. Planning Unit L2
4. Vegetation–Soil Unit mixed grass – 9002
5. Soil Map Symbol 02/C2N
6. Surname Ward
7. Date 1 mo 74 yr
8. Area –
9. County 075
10. Location Sec. 34, T. 3S, R. 45E
11. Photo No. –
12. Writeup No. 15
13. File No. –
14. Parent Rock Colluvium and interbedded siltstone and shale
15. Formation Name Fort Union
16. Surface Conditions (percent) Stone – 0 Rock – 0
17. Land Conditions Alkaline Non Saline Non Water table > 10'
18. Landform Residual slope in rolling hills
19. Slope (percent) 6/12 ☐ Single ☒ Complex
20. Aspect NW
21. Elevation 3180
22. Present Erosion Type SSF – – – Class 2
23. Hydrologic Group –
24. Precipitation (in) 13.7 1st , 2nd , 3rd , 4th
25. Temperature – – Air – – Soil
26. Frost-free Days 130 28°
27. Drainage Class Mod well drained
28. Infiltration High
29. Percolation Mod to slow
30. ERD 9 in
31. AWC 4.7 in

32. HORIZON	33. THICKNESS	34. COLOR DRY / MOIST: MATRIX	34. COLOR DRY / MOIST: MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH) 1-5 CaCl2	42. BOUNDARY
A1	0-5	D-(10YR 6/3) m-(10YR 4/4)		L	fine + med granular	D - soft m - friable	None	many		++ 8.3 7.5	Clear wavy
B2	5-9	D-(10YR 6/4) m-(10YR 5/6)	lime on ped faces	SiL	wk prismatic to granular	D - soft m - friable	None	many		+++ 8.7 7.7	gradual
B3CA	9-18	D-(10YR 6/3) m-(10YR 5/4)	threads and soil pockets lime	Hy. SiL	Wk. prismatic to blky	D - sli Hard m - friable	None	many to few		+++ 9.0 7.9	Abrupt
C1CA	18-26	D-(2.5Y 7/2) m-(2.5Y 6/4)	Lime on ped faces + soil pockets	SiCL	Decomposed Si shale			Few to none		+++ 8.8 8.1	Abrupt
C2CS	26-50	D-(2.5Y 7/0) m(2.5Y 6/4)	(10YR 6/4) (GYP 34" to 40")	SiCL	Consolidated shale layered and variable colors			none		+	
C3	50-60	D-(10YR 6/1) m(10YR 5/2)	(10YR 6/8)	SiCL							

This soil represents the shallower soils in this delineation. The highly weathered shale does not exhibit adverse properties common to most shale in the area. The native vegetation includes slender wheat, green needle, needle and thread, and prairie june. Pine occupies the stone breaks along natural drain that divides the area. Newly deposited material along upper slopes grows western wheatgrass and has an [illegible] surface soil.

(Instructions inside back cover)

Form 7310–9 (December 1970)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION–SOIL DESCRIPTION

1. State 25
2. District 02
3. Planning Unit 12
4. Vegetation–Soil Unit mixed grasses 9006
5. Soil Map Symbol 02/ASM
6. Surname Ward
7. Date 02 mo 74 yr
8. Area –
9. County 075
10. Location Sec. 34, T. 3S, R. 45E
11. Photo No. ----------
12. Writeup No. 16
13. File No. ------
14. Parent Rock Local alluvium from interbedded siltstone shale
15. Formation Name Fort Union
16. Surface Conditions (percent) Stone – 0 Rock – 0
17. Land Conditions Alkaline Mod to High (Subsoil) Saline High (Subsoil) Water table >10'
18. Landform Intermittent natural drn. narrow valley floor
19. Slope (percent) 0/2 ☒ Single ☐ Complex
20. Aspect SE
21. Elevation 3185'
22. Present Erosion Type SSF --- Class 2
23. Hydrologic Group –
24. Precipitation (in) 13.7 1st , 2nd , 3rd , 4th
25. Temperature -- Air -- Soil
26. Frost-free Days 130 > 28°
27. Drainage Class Mod well drained
28. Infiltration Moderate
29. Percolation [illegible] slow
30. ERD 2 in
31. AWC 10.0 in

32. HORIZON	33. THICKNESS	34. COLOR DRY MOIST MATRIX	MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH)	42. BOUNDARY
A1	0-2	D-(10YR 7/2) m-(10YR 4/2)		CL	platy	D- soft m friable	None	Many	None	W	Abrupt
AC	2-5	D-(10YR 7/2) m-(10YR 4/2)		CL	fine blky	D- Hard m- friable		many		+ 7.7 7.5	diffuse
C1	5-21	D-(10YR 7/2) m-(10YR 4/2)		CL	med ang. blky	D Hard m sli. firm		many to few		+	abrupt
C2	21-38	D-(10YR 7/1) m-(10YR 5/2)	thin layers of lignite + gyp	CL	depositional layering	D- m- firm		few		++ 7.9 7.7	abrupt
C3cs	38-60	D-(10YR 7/1) m-(10YR 4/2)	mod + large pockets of gypsum	LtC	massive	D- m firm		few to none		+ 8.1 7.9	abrupt
C4	60-108	D- m-	pockets of lignite	MC	massive	D M very firm		None		+ 8.1 8.0	[illegible]
C5cs	108-120	D-(10YR 6/1) m-(10YR 3/2)	some gyp in small pockets	MC	massive	D- m- firm				8.1 8.0	

Sampled with hydraulic core machine

(Salinity starts at 21" and below 60" it becomes saline alkali)

This soil typifies the recent alluvial soils in narrow valleys of the dendritic drainages that extend into the uplands that are derived largely from clayey and silty shales. This soil supports a good stand of western wheatgrass where the surface soil is intact and seasonal water tables are not at or near the surface. Salt tolerant sedge grows in these more adverse locations.

(Instructions inside back cover)

Form 7310-9 (December 1970)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION–SOIL DESCRIPTION

1. State 25
2. District 02
3. Planning Unit 12
4. Vegetation–Soil Unit mixed grasses , 9005
5. Soil Map Symbol 83 / Atm
6. Surname [illegible]
7. Date 07 mo 74 yr
8. Area --
9. County 075
10. Location Sec. 34, T. 3 S, R. 45 E
11. Photo No. --
12. Writeup No. 18
13. File No. --
14. Parent Rock Interbedded sandstone siltstone and shale
15. Formation Name Fort Union
16. Surface Conditions (percent) Stone – 2 Rock – 0
17. Land Conditions Alkaline Non Saline Non Water table > 5'
18. Landform Tabular divide
19. Slope (percent) 0/2 ☒ Single ☐ Complex
20. Aspect N
21. Elevation 3265'
22. Present Erosion Type SSF --- Class L
23. Hydrologic Group -
24. Precipitation (in) 13.7 1st , 2nd , 3rd , 4th
25. Temperature -- Air -- Soil
26. Frost-free Days 130 > 28°
27. Drainage Class Mod well drained
28. Infiltration high
29. Percolation moderate
30. ERD 14 in
31. AWC 9.4 in

32. HORIZON	33. THICKNESS	34. COLOR DRY / MOIST: MATRIX	34. MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH) 1-5 CaCl2	42. BOUNDARY
A1	0-2	D·(10YR 6/2) m·(10YR 4/2)		fSL	crumb	D-soft m-friable		many		N	gradual
B2	2-8	D·(10YR 6/3) m (10YR 5/3)		L	med granular	D soft m-friable		many		N 8.0 7.3	gradual
B3CA	8-24	D·(10YR 7/2) m (10YR 6/3)		SiL	weak angular blocky	D sl. Hard m-friable		many to com		+++ 8.3 7.8	grad
C1CA	24-44	(10YR 8/3) m (10YR 7/8)		Hvsil/Ltsicl	weak massive	D soft m friable		very few to none		+++ 8.8 8.0	abrupt
C2CA	44-62	(10YR 8/1) m (10YR 7/1)		fSL	weakly cemented sandstone	D m friable		none		+++ 8.8 8.1	

This profile represents the moderately deep residual soils of the upland tabular divides. It supports a good to excellent cover but, may have a few slick spots along the internal margin where it joins Series 9007. Grasses include green needle, Blue grama, needle and thread and prairie june.

(Instructions inside back cover)

Form 7310–9 (December 1970)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION–SOIL DESCRIPTION

1. State 25
2. District 02
3. Planning Unit 12
4. Vegetation–Soil Unit Mixed grasses – – / – 9008 – –
5. Soil Map Symbol – $\frac{08}{ATN}$
6. Surname
7. Date – – mo – – yr
8. Area – –
9. County 075
10. Location Sec. 34, T. 3S, R. 45E
11. Photo No – – – – – – – – – – –
12. Writeup No. – – – – 19
13. File No. – – – – – – –
14. Parent Rock Sandstone
15. Formation Name Fort Union
16. Surface Conditions *(percent)* Stone – D Rock – D
17. Land Conditions Alkaline Non Saline Non Water table > 10'
18. Landform Tabular divide
19. Slope *(percent)* 0–3 ☒ Single ☐ Complex
20. Aspect NW
21. Elevation 3170'
22. Present Erosion Type SSF – – – Class 1
23. Hydrologic Group –
24. Precipitation *(in)* 13.7 1st , 2nd , 3rd , 4th
25. Temperature – – Air – – Soil
26. Frost-free Days 130 > 28°
27. Drainage Class very well drained
28. Infiltration High
29. Percolation high
30. ERD 15 in
31. AWC 5.0 in

32. HORIZON	33. THICKNESS	34. COLOR DRY / MOIST: MATRIX	34. COLOR DRY / MOIST: MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL	41. REACTION (pH) 1-5 CaCl2	42. BOUNDARY
A1	0-2	D-(5YR 6/3) m-(5YR 4/3)		fSL	fine crumb	D - Soft m-Vfriable	None	Many		8.3 6.8	clear wavy
AC	2-16	D-(5YR 6/3) m-(5YR 4/4)		fSL	med wk prismatic to f+med gran.	D - soft m friable	None	Many			diffuse
C1	16-25	D-(7.5YR 7/4) m-(7.5YR 6/2)		fSL	weak sub-angblky	D-Soft m. friable	None	Many		8.1 7.4	abrupt
C2	25-31	D-(7.5YR 8/4) m-(7.5YR 6/2)		fSL	Consolidated SS breaks to loose	D-V Sli hard. m-v-friable		few	20% sand-stone Shards	8.4 7.9	gradual
C3	31-72	D-(10R 6/8) m.(10R 6/6)	sandstone layers (5YR 3/4)	S	consolidated ss-breaks to loose	D- Soft m- friable		few to none		8.7 8.2	
C4	72-102	D (10R 6/8) m. (10R 6/6)	sandstone layers (5YR 7/8) & (10YR 8/2)	S	Consolidated ss breaks to loose	D- soft m- friable		None		8.9 8.2	
						Stopped by Hard S.S.					

This Soil represents the equivalent of Cushman series that have been burned. The soil is of excellent quality but shallow to sandstone with very low (AWC). Needle and thread, blue groma and slender wheat are the dominant grasses. Silver sage and a low shrub (brownish red stems) are common.

(Instructions inside back cover)

Form 7310–9 (December 1970)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION–SOIL DESCRIPTION

1. State 25
2. District 02
3. Planning Unit 12
4. Vegetation–Soil Unit Mixed grasses, - 9003 -
5. Soil Map Symbol - $\frac{03}{C3N}$
6. Surname - - Ward
7. Date 08 mo 74 yr
8. Area -
9. County 075
10. Location Sec. - 34, T. - 3 S, R. 45E
11. Photo No. - - - - - - - - - - -
12. Writeup No. - - - - 20
13. File No. - - - - - - -
14. Parent Rock Shale.
15. Formation Name Fort Union
16. Surface Conditions (percent) Stone – 0 Rock – 0
17. Land Conditions Alkaline Non Saline moderate (Subsoil) Water table >10'
18. Landform Residual slopes in rolling hills
19. Slope (percent) 2-12 ☐ Single ☒ Complex
20. Aspect NW
21. Elevation - 3215'
22. Present Erosion Type SSF - - - Class -
23. Hydrologic Group -
24. Precipitation (in) 13.7 1st , 2nd , 3rd , 4th
25. Temperature - - Air - - Soil
26. Frost-free Days 130 > 28°
27. Drainage Class Mod. well drained
28. Infiltration Moderate
29. Percolation Slow to V slow
30. ERD - 8 in
31. AWC - 3.2 in

32. HORIZON	33. THICKNESS	34. COLOR DRY / MOIST: MATRIX	34. COLOR DRY / MOIST: MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH) 1-5 CaCl₂	42. BOUNDARY
A1	0-1	D-(10YR 7/2) m-(10YR 6/3)		SiCL	fine and med granular	D- soft m- friable	None	many			clear
AC	1-6	D- (10YR 7/3) m-(10YR 6/3)		SiCL	massive-to med blky	D- Hard m- friable	None	& many		8.1 7.7	gradual
C1	6-16	D- m-(10YR 7/6)	(Decomposed Shale.)	Hy SiCL	Weak Sub-angular, blocky	D- soft m friable	None	many to few,		7.9 7.8	abrupt
C2cs	16-32	D- m. (10YR 5/3)		SiC	slightly weathered			few		8.0 7.9	
C3cs	32-44	D- m-(10YR 5/6)		SiC	shale. Very compact			few to none		8.0 8.0	
C4cs	44-60	D- m. (10YR 6/6)		Hv SiC	and dense					7.3 7.3	
C5cs	60-72	D- m- (10YR 5/4)		MC	in place, many hard					5.1 5.9	
C6cs	72-90	D- m-(10YR 3/1)		MC	shale flakes					4.7 5.1	
C7	90-100	Coal								—	
C8cs	100-118	D- m-(10YR 6/1)	med pocket of white taste-less salts	MC						4.4 4.7	

This soil represents the fine textured non saline surface, clayey ridge. The stand and cover of western wheat, strdr. wheat and side oats grown is fair to poor - numerous shale outcrops (Salinity starts at 16")

(Instructions inside back cover)

Form 7310–9 (December 1970)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION–SOIL DESCRIPTION

1. State 25
2. District 02
3. Planning Unit L2
4. Vegetation–Soil Unit mixed grasses, 9002
5. Soil Map Symbol 02 - ZIN
6. Surname Ward
7. Date 07 mo 74 yr
8. Area –
9. County 075
10. Location Sec. 34, T. 3S, R. 45E
11. Photo No. – – – – –
12. Writeup No. 21
13. File No. – – – – –
14. Parent Rock silty shale
15. Formation Name Fort Union
16. Surface Conditions (percent) Stone – 0 Rock – 0
17. Land Conditions Alkaline Non Saline Non Water table > 10'
18. Landform [illegible]
19. Slope (percent) 6-12 ☐ Single ☒ Complex
20. Aspect NW
21. Elevation 3180'
22. Present Erosion Type SSF – – – Class 2
23. Hydrologic Group –
24. Precipitation (in) 13.7 1st , 2nd , 3rd , 4th
25. Temperature – – Air – – Soil
26. Frost-free Days 130 > 28°
27. Drainage Class Well drained
28. Infiltration High
29. Percolation moderate
30. ERD 13 in
31. AWC 5.6 in

32. HORIZON	33. THICKNESS	34. COLOR DRY / MOIST: MATRIX	MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH) 1-5 CaCl2	42. BOUNDARY
A11	0-1	D-(10YR 7/3) m-(10YR 5/3)		LtCL	fine granular	D-soft m-friable	None	many		7.0 7.1	Gradual
A12	1-5	D-(10YR 7/3) m-(10YR 5/3)		LtCL	Weak ang Blky to fine Granular	D-soft m-friable	None	many			wavy
B2CA	5-16	D-(10YR 7/6) m-(10YR 5/6)		LtL	weak prismatic	D-soft m-friable	None	many		+++ 7.2 7.5	abrupt
C1CA	16-24	D-(10YR) m-(10YR 6/6)		L	weathered shale	D-soft m-friable		many to com	14 Hard siltsh.	+++ 7.6 7.7	clear smooth
C2	24-32	D-(10YR 8/3) m-(10YR 7/6)		HvfSL	consolidated si shale	Layered and hard in place friable		com to few		8.1 7.7	
C3	32-60	D-(2.5Y 7/2) m-(2.5Y 6/2)		HvSiL	consolidated si shale	Layered Hard in place friable		few		8.2 7.8	
C4	60-78	D-(10YR 7/3) m-(10YR 6/2)		HvSiL	consolidated si shale	Hard in place breaks friable				8.3 7.9	
C5	78-88	D-(10YR 8/4) m-(10YR 7/4)		fSL	consolidated si shale	Hard breaks down fairly easy				8.5 8.0	
C6	88-112	D-(10YR 7/1) m-(10YR 6/2)		LtCL	''	Hard - very firm out				8.4 8.0	
C7	112-116	D-(10YR 7/3) m-(10YR 6/4)		SiCL		Hard - firm out					
C8cs	116-120	D-(2.5Y 7/1) m-(2.5Y 6/6)	gypsum	SiCL		Hard - firm out				8.4 7.9	

(Instructions inside back cover)

Form 7310–9 (December 1970)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION–SOIL DESCRIPTION

1. State 25
2. District 02
3. Planning Unit 12
4. Vegetation–Soil Unit mixed grasses – / – 9003 –
5. Soil Map Symbol – 03/D3N
6. Surname – – – – Ward – – – – – – – – –
7. Date 08 mo 74 yr
8. Area –
9. County 075
10. Location Sec. – 34, T. – 3S, R. 45E
11. Photo No. – – – – – – – – – – –
12. Writeup No. – – 22
13. File No. – – – – – –
14. Parent Rock Colluvium and interbedded Siltstone and shale
15. Formation Name Fort Union
16. Surface Conditions (percent) Stone – 0 Rock – 0
17. Land Conditions Alkaline Non Saline Non Water table > 5'
18. Landform Residual slope in rolling hills
19. Slope (percent) 4-12 ☐ Single ☒ Complex
20. Aspect W
21. Elevation 3210'
22. Present Erosion Type SSF – – – Class 3
23. Hydrologic Group –
24. Precipitation (in) 13.7 1st , 2nd , 3rd , 4th
25. Temperature – – Air – – Soil
26. Frost-free Days 130 > 28°
27. Drainage Class well drained
28. Infiltration Mod to high
29. Percolation mod to high
30. ERD – 8 in
31. AWC – 4.8 in

32. HORIZON	33. THICKNESS in	34. COLOR DRY MOIST MATRIX	MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH)	42. BOUNDARY
A1	0-3	D (10YR 7/3) m (10YR 6/6)		SiCL	med & fine granular	D-sl. hard m-firm	None	Many		N	Clear wavy
AC	3-8	D (10YR 6/3) m (10YR 5/4)		SiCL	wk prismatic & med & fine granular	D- Hard m-firm		Many		+	clear wavy
C1	8-16	D (10YR 6/3) m (10YR 5/2)	(10YR 6/6)	SiCL	to prismatic to ang. blocky	D- Hard m-v firm		Many		++	abrupt
C2CA	16-24	D-(10YR 7/3) m-(10YR 6/2)		L	weathered sandy shale	D- soft m- friable		few		+++	clear smooth
C3	24-36	D- (2.5Y 7/2) m- (2.5Y 6/3)		SL	Consolidated	firm in place breaks down easily		few to none		++	
C4	36-44	D (10YR 7/2) m (10YR 6/2)		SiL	fine sandstone	..				+	
C5	44-52	D (2.5Y 8/0) m (2.5Y 7/0)		SL		very firm in place breaks down easily				N	
C6	52-60	D (2.5Y 8/0) m (2.5Y 6/0)	D m (10YR 7/6)	SL		..				N	

This profile represents the residual soils that are shallow over sandstone. It is typical of the Non saline nonalkaline weakly consolidated sandstone. Vegetative cover is fair to good and consists of sideoats grama, slender wheat, needle and thread and western wheatgrass. Pine also dot the area and there are scattered big sage.

(Instructions inside back cover)

Form 7310-9 (December 1970)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION–SOIL DESCRIPTION

1. State 25
2. District 02
3. Planning Unit 12
4. Vegetation–Soil Unit mixed grasses – 9202
5. Soil Map Symbol 02/C2H
6. Surname Ward
7. Date 23 mo 74 yr
8. Area –
9. County 075
10. Location Sec. 34, T. 3S, R. 45E
11. Photo No. –
12. Writeup No. 23
13. File No. –
14. Parent Rock silty Shale
15. Formation Name Fort Union
16. Surface Conditions (percent) Stone – 0 Rock – 0
17. Land Conditions Alkaline Non Saline mod (subsoil) Water table
18. Landform Colluvial Slope in Rolling hills
19. Slope (percent) 4/10 ☒ Single ☐ Complex
20. Aspect NE
21. Elevation 3215'
22. Present Erosion Type SSF – – – Class –
23. Hydrologic Group –
24. Precipitation (in) 13.7 1st , 2nd , 3rd , 4th
25. Temperature – – Air – – Soil
26. Frost-free Days 130 > 28°
27. Drainage Class well drained
28. Infiltration moderate
29. Percolation mod to slow
30. ERD 11 in
31. AWC 10.5 in

32. HORIZON	33. THICKNESS	34. COLOR DRY MOIST MATRIX	34. MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL	41. REACTION (pH) 1-5 CaCl2	42. BOUNDARY
A1	0-2	D-(10YR 7/3) m-(10YR 6/3)		SCL	fine + mod granular	D- soft m- friable	None	many	none	N	wavy
B2t	2-8	D m (10YR 5/2)		Lt C	strong prismatic	D- Very hard m- very firm	few thin patchy	many		N	clear wavy
B3CA	8-16	D- m- (10YR 5/2)		SiCL	med ang. Blky	D Hard m very firm		many		++	gradual
C1CA	16-20	D m (2.5Y 6/3)	Lime on rock shards and in pockets	SiCL	med ang. Blky	D- Hard m- firm		many to com	many fine shards gss	+++	abrupt
C2	20-33	D- m. (2.5Y 5/3)	Lime and gyp in threads + pockets	SiC		D- m- firm		com to few		++	
C3	33-36	D- m- (2.5Y 6/4)		SCL		D m friable		few to none		++	
C4	36-60	D- m- (2.5Y 5/3)		SiC		D- m- firm		none		+	

Good stand and growth of P June, G needle, W wheat, slender wheat, a few Sideoats grama and some forbes. Rolling slopes and grassed ridges

(Salinity starts at 16")

(Instructions inside back cover)

Form 7310–9 (December 1970)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION–SOIL DESCRIPTION

1. State 25
2. District 02
3. Planning Unit 12
4. Vegetation–Soil Unit mixed grasses - 1 - 9003
5. Soil Map Symbol 03/D3N
6. Surname Ward
7. Date 07 mo 74 yr
8. Area --
9. County 071
10. Location Sec. 2, T. 4S, R. 45E
11. Photo No. ----------
12. Writeup No. 1
13. File No. ------
14. Parent Rock Interbedded siltstone and shale
15. Formation Name Fort Union
16. Surface Conditions (*percent*) Stone – 1 Rock – 1
17. Land Conditions Alkaline mod Saline mod Water table > 5'
18. Landform Rolling hills in Uplands
19. Slope (*percent*) 3/12 ☐ Single ☒ Complex
20. Aspect N
21. Elevation 3235'
22. Present Erosion Type rill + sheet SSF --- Class 3
23. Hydrologic Group -
24. Precipitation (*in*) 13.7 1st , 2nd , 3rd , 4th
25. Temperature -- Air -- Soil
26. Frost-free Days 130 > 28°
27. Drainage Class Mod well drained
28. Infiltration Moderate
29. Percolation Very slow
30. ERD 9 in
31. AWC 4.8 in

32. HORIZON	33. THICKNESS	34. COLOR DRY/MOIST MATRIX	MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION + lime (pH) 1-5 CaCl₂	42. BOUNDARY
A1	0-2	D (10YR 7/1) m (10YR 5/2)	None	SiCL	st granule	D-soft m friable	None	many	None		Abrupt
AC	2-8	D-(10YR 7/3) m(10YR 5/2)	None	SiCL	Prismatic & Ang. Blky	D hard m firm	None	many	None	8.0 7.5	Abrupt
C1	8-16	D-(10YR 7/2) m(10YR 6/1)	slight lime on peds	SiCL	Ang blky	D-Hard m-firm	None	Comm		++ 8.1 7.7	gradual
C2	16-22	D-(10YR 7/2) m(10YR 6/1)	few threads of lime	SiCL	massive	D-Hard M-v firm		few		+ 7.9 7.7	Abrupt
C3	22-26	D-(10YR 7/3) m(10YR 6/2)		fSCL	Consolidated Ft Union	D-Hard m-firm		few to		Non	gradual
C4	26-40	D(10YR 7/1) m(10YR 6/1)		vfSCL	formation	D-Hard m firm		none		Non 7.9 7.8	Abrupt
C5	40-54	D(10YR 7/3) m (10YR 6/6)		SiL	thin layers	D-soft m friable				Non 8.0 7.9	Abrupt
C6	54-60	(10YR 6/3) m (7.5YR 5/6)		Lt SiCL	(color varies)	D-Hard m firm				Non 8.3 8.0	

[Salinity starts at 24" & Alkalinity at 41"]

This profile is located on a moderately steep residual slope below cliff forming sandstone. Massive blocks and thin sandstone flagstone is common below scarp. Lenticular sandstone is exposed also. Native vegetation consists of Prairie June, slender wheat and western wheat grass. Some clover and many forbs indicate the low productivity of this soil.

(Instructions inside back cover)

Form 7310–9 (December 1970)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION–SOIL DESCRIPTION

1. State 25
2. District 02
3. Planning Unit LZ
4. Vegetation–Soil Unit Mixed grasses 9003
5. Soil Map Symbol 83 D3N
6. Surname Ward
7. Date 07 mo 24 yr
8. Area ✓
9. County 075
10. Location Sec. 2, T. 4S, R. 45E
11. Photo No.
12. Writeup No. 2
13. File No.
14. Parent Rock Silty Shale
15. Formation Name Fort Union
16. Surface Conditions (percent) Stone – 0 Rock – 0
17. Land Conditions Alkaline Very (subsoil) Saline Non Water table > 6'
18. Landform Rolling hills
19. Slope (percent) 6/12 ☒ Single ☐ Complex
20. Aspect N
21. Elevation 3165'
22. Present Erosion Type Sheet & gully SSF Class 3
23. Hydrologic Group –
24. Precipitation (in) 13.7 1st, 2nd, 3rd, 4th
25. Temperature Air Soil
26. Frost-free Days 130 > 28°
27. Drainage Class Mod. well drained
28. Infiltration moderate
29. Percolation very slow
30. ERD 10 in
31. AWC 3.2 in

32. HORIZON	33. THICKNESS	34. COLOR DRY MOIST MATRIX	34. MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES VOL	41. REACTION + lime, pH 1-5 CaCl2	42. BOUNDARY
A1	0-4	D (10YR 6/4) m (10YR 5/2)	None	SiL	fine granular	D - soft m - friable	None	many	None	++ 7.7 7.7	clear wavy
AC	4-18	(10YR 7/3) m (10YR 5/4)	Threads and pockets of lime	SiCL	wk prismatic breaks to med ang blky	D - Hard m - friable	None	many	none	+++ 8.8 8.0	wavy
C1	18-36	(10YR 7/2) m (10YR 6/3)	threads of lime	Hv SiL	weak ang blky	D Sl. Hard m friable	None	com	None	++ 9.2 8.5	diffuse
C2	36-54	(10YR 7/2) m (10YR 6/3)	threads of lime	Lt SiCL	massive	D - Hard m firm		few to ~~none~~	None	++ 9.5 8.5	Abrupt
C3	54-64	(2.5Y 6/1) m (2.5Y 4/1)		SiCL	Layered Shale	D - very Hard m - firm/friable		None	None	+ 9.3 8.5	

Surface soil depth is quite variable ranges from 10 to 36 inches. A fair to good stand of slender wheat, prairie june, side-oats-grama, and green needle grass covers most of the area. Small gullies are relatively stable at present. Thin silty soils are common on the eroded weak ridges. Subsoil is very disperse.

(Alkalinity starts at 18")

(Instructions inside back cover)

Form 7310–9 (December 1970)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION–SOIL DESCRIPTION

1. State 25	2. District 02	3. Planning Unit 12	4. Vegetation–Soil Unit Mix-grass-B sage – 1 – 9007	5. Soil Map Symbol 89 B2N	6. Surname Ward	7. Date 02 mo 24 yr
8. Area 2	9. County 075	10. Location Sec. 2, T. 4S, R. 45E	11. Photo No.	12. Writeup No. 3	13. File No.	14. Parent Rock Shale

15. Formation Name: Fort Union.
16. Surface Conditions (percent): Stone – 0 Rock – 0
17. Land Conditions: Alkaline Mod. to high (subsoil) Saline Mod to high Water table > 9'
18. Landform: Tabular divide
19. Slope (percent) 0/2 ☒ Single ☐ Complex
20. Aspect: NW
21. Elevation: 3265
22. Present Erosion: Type Sheet SSF – – – Class 2
23. Hydrologic Group: –
24. Precipitation (in) 13.7 1st , 2nd , 3rd , 4th
25. Temperature – – Air – – Soil
26. Frost-free Days 130 > 28°
27. Drainage Class: Mod. well-drained
28. Infiltration: Mod to slow
29. Percolation: slow
30. ERD: 11 in
31. AWC: 1.8 in

32. HORIZON	33. THICKNESS	34. COLOR DRY / MOIST: MATRIX	34. MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION +Lime (pH) 1-5 CaCl2	42. BOUNDARY
A1	0-2	D (10YR 6/2) m (10YR 5/2)		SiL	platy	D-Sl. Hard m-friable	None	many	None	Non	Clear
B2T	2-5	D (10YR 6/4) m (10YR 4/3)		SiCL	St. prismatic	D-Hard m-firm	thin Patchy	many	None	++ 8.3 7.7	Abrupt
C1CA	5-18	D (10YR 7/2) m (10YR 5/3)		SiCL	weak med blky	D Sl. Hard m-friable	None	many	None	+++ 8.3 7.7	Abrupt
C2CA	18-30	D (10YR 7/2) m (10YR 5/3)		SiCL	massive	D-Hard m-firm	None	few	None	+++ 8.8 8.2	Abrupt
C3	30-56	D (2.5Y 7/3) m (2.5Y 6/4)		SiCL	Consolidated shale	D- m-firm		~~few~~ few to none		++ 8.3 8.2	
C4	56-60	Coal/shale								Non	
C5	60-72	D (10YR 7/1) M (10YR 6/1)		SiL		D- m-friable				Non 8.3 8.1	
C6	72-102	D (10YR 7/1) m (10YR 6/1)	Lignite and m (2.5Y 8/6)	SiCL		D m-firm				Non 8.1 7.9	

Smooth to slightly undulating tabular divide. A few small and large slick spots are in this area. A good stand of B.grama, green needle, needle and thread and prairie junegrass covers most of the area. Big sage occurs in localized scattered stand.

(Salinity and alkalinity starts at 18")

(Instructions inside back cover)

Form 7310–9 (December 1970)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION–SOIL DESCRIPTION

1. State 25	2. District 02	3. Planning Unit L2	4. Vegetation–Soil Unit mixed grasses 9004	5. Soil Map Symbol 84/BZM	6. Surname Ware	7. Date 02 mo 74 yr

8. Area ✓	9. County 075	10. Location Sec. 2, T. 4S, R. 45E	11. Photo No. ----------	12. Writeup No. ----4	13. File No. ------	14. Parent Rock Alluvium

15. Formation Name Fort Union	16. Surface Conditions *(percent)* Stone – 2 Rock – 1	17. Land Conditions Alkaline Non Saline non/a moderate (subsoil) Water table >10'	18. Landform Undulating ridgetop

19. Slope *(percent)* 2/4 ☒ Single ☐ Complex	20. Aspect SE	21. Elevation 3280'	22. Present Erosion None Type SSF --- Class 2	23. Hydrologic Group -

24. Precipitation *(in)* 13.7 1st , 2nd , 3rd , 4th	25. Temperature -- Air -- Soil	26. Frost-free Days 130 > 28°	27. Drainage Class Well drained	28. Infiltration High	29. Percolation moderate to high	30. ERD 19 in	31. AWC 9.2 in

32. HORIZON	33. THICKNESS	34. COLOR DRY / MOIST MATRIX	34. COLOR MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES VOL.	41. REACTION 1-5 acid	42. BOUNDARY
A1	0-2	D-(10YR 4/2) m-(10YR 5/3)		FSL	fine [illegible]	D - soft m- friable	None	Many	6	++	clear wavy
B2	2-8	D-(10YR 6/2) m (10YR 5/3)		FSL	med subangular blocky	D- Sl. Hard m- friable	None	many	2	+++ 8.1 7.4	gradual
B3CA	8-24	D-(10YR 7/2) m-(10YR 6/3)	Lime threads and few pockets	Hv L	med prismatic to fine subang blk	D- Sl. Hard m- friable	None	many		+++ 8.5 7.8	gradual
C1CA	24-36	D-(2.5Y 7/3) m-(2.5Y 4/3)	lime threads and few pockets	CL	subangular blocks	D - Sl. Hard m - friable		Many to com		+++ 8.7 7.9	abrupt
C2CA	36-60	D-(2.5Y 7/4) m-(2.5Y 5/3)	lime in pockets and on ped faces	Lt CL	massive	D Sl. Hard m- friable		Few to None	< 2	+++ 9.0 8.0	
C3CA	60-69	D(2.5Y 7/2) m-(2.5Y 6/2)	Heavy lime in pockets and peds one 1½ to 2"	Lt CL		m- friable				+++	
C4CA	69-93	(2.5Y 8/2) m (2.5Y 7/4)	gyp in shale layer	Hv L		m - friable	None		< 2	+++ 8.8 8.0	
C5CA	93-114	(2.5Y 8/3) m-(2.5Y 7/3)		Hv L		m- friable	None			+++ 8.8 7.9	

An excellent stand of green needle, needle and thread, blue grama, prairie junc, and slender wheat cover the area. Big sage and threadleaf sedge are common but scattered. Surface rock is ablation material from very old burn areas. These high quality soils are underlain by shale but, often at depths of more than 10 feet. (Salinity starts at 93")

(Instructions inside back cover)

Form 7310–9 (December 1970)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION–SOIL DESCRIPTION

1. State 25
2. District 02
3. Planning Unit 12
4. Vegetation–Soil Unit Mixed grasses , 9004
5. Soil Map Symbol 84/C-2M
6. Surname Ward
7. Date 02 mo 24 yr
8. Area –
9. County 075
10. Location Sec. 2, T. 4S, R. 45E
11. Photo No. –
12. Writeup No. 5
13. File No. –
14. Parent Rock Alluvium
15. Formation Name Fort Union
16. Surface Conditions (percent) Stone – 0 Rock – 0
17. Land Conditions Alkaline Non Saline Non Water table > 20'
18. Landform Rolling hills
19. Slope (percent) 4-12 ☐ Single ☒ Complex
20. Aspect E
21. Elevation 3155'
22. Present Erosion None Type SSF – – – Class 2
23. Hydrologic Group –
24. Precipitation (in) 13.7 1st , 2nd , 3rd , 4th
25. Temperature – – Air – – Soil
26. Frost-free Days 130 – – > 28°
27. Drainage Class Well drained
28. Infiltration High
29. Percolation Mod to high
30. ERD 19 in
31. AWC 8.6 in

32. HORIZON	33. THICKNESS	34. COLOR DRY / MOIST MATRIX	34. MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL	41. REACTION lime (pH) 1-5 CaCl2	42. BOUNDARY
A1	0-4	D-(10YR 6/3) m (10YR 4/3)		Lt L	fine granular	D-soft m-friable	None	many	None	+++	clear
B2	4-14	D-(10YR 7/3) m (10YR 5/3)	Light lime on peds	Lt L	weakly prism. to med ang Bky	D-soft m-friable	None	many	None	+++ 8.5 7.7	gradual
C1CA	14-32	D-(10YR 7/2) m-(10YR 6/3)	moderate lime on peds	VfSL	weak fine to med Bky to med gran	D-soft m-friable	None	many to common	None	+++ 8.7 7.9	gradual
C2CA	32-60	D-(10YR 7/2) m-(10YR 6/3)	Slight lime visible in moist condition	VfSL		D-soft m-friable		few	None	+++ 8.9 8.1	
C3CA	60-84	D-(10YR 6/4) m-(10YR 5/3)	slight lime visible in moist condition	VfSL		D-soft m-friable		few to None	None	+++ 8.8 8.2	
C4CA	84-102	D-(2.5Y 8/2) m (2.5Y 7/3)	slight lime visible in moist condition	VfSL		D-soft m-friable			None	+++ 9.0 8.2	
C5CA	102-120	D (2.5Y 7/3) m (2.5Y 6/3)	slight lime visible in moist condition	Hv.VfSL		D-soft m-friable			one 2½ stone	+++ 8.9 8.2	

An excellent stand of slenderwheat, green needle, prairie junc, and side oats grama cover the area. Scattered big sage and milkweed occur at random. Surface stone amounting to percent occurs in a narrow band (90% area, along the upper slope limits. A short very steep slope into a natural is included in this delination. The alluvium was derived from older alluvial deposits.

(Instructions inside back cover)

Form 7310-9 (December 1970)

U S DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION-SOIL DESCRIPTION

1. State 25
2. District 02
3. Planning Unit 12
4. Vegetation-Soil Unit mixed grasses 9004
5. Soil Map Symbol 04/C2M
6. Surname Ward
7. Date 02 mo 74 yr
8. Area —
9. County 075
10. Location Sec. 2, T. 4S, R. 45E
11. Photo No.
12. Writeup No. 6
13. File No.
14. Parent Rock Alluvium
15. Formation Name Fort Union
16. Surface Conditions (percent) Stone – 0 Rock – 0
17. Land Conditions Alkaline Non to slight Saline Non to slight (subsoil) Water table > 8'
18. Landform Rolling hills
19. Slope (percent) 4/12 ☒ Single ☐ Complex
20. Aspect NE
21. Elevation 3145'
22. Present Erosion None Type SSF – – – Class 2
23. Hydrologic Group –
24. Precipitation (in) 13.7 1st , 2nd , 3rd , 4th
25. Temperature – – Air – – Soil
26. Frost-free Days 130 > 28°
27. Drainage Class Well drained
28. Infiltration Mod to high
29. Percolation Mod to slow
30. ERD 19 in
31. AWC 8.5 in

32. HORIZON	33. THICKNESS	34. COLOR DRY MOIST MATRIX	MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL	41. REACTION (pH) 1-5 (CaCl2	42. BOUNDARY
A1	0-2	D-(10YR 5/3) m (10YR [illegible]/3)		VFSL	platy	D - soft m - friable	None	many	None	+ + +	Abrupt
B2	2-8	D- (10YR 5/4) m (10YR 4/3		Hv.VFSL	weak prismatic to fine granular	D - soft m - friable	None	many	3	+ + + 8.4 7.7	wavy
B	8-22	D- (10YR 6/3) m- (10YR 5/4)		SiL	med Sub AngBlky	D- Sli hard m- friable	None	many	None	+ + + 8.6 7.9	diffuse
C1CA	22-40	D- (10YR 7/2) m- (10YR 5/4)		Lt SiCL	Massive	D Sli hard m- friable		few	None	+ + + 9.1 8.1	
C2CA	40-64	D- (2.5Y 7/2) m- (2.5Y 6/4)		Lt. SiCL	Massive	D Sli hard m- friable		few to none	3	+ + + 9.2 8.2	
C3CA	64-86	D- (2.5Y 7/2 m- (2.5Y 4/4)		Lt. SiCL	massive	D Sli hard m- friable			11	+ + + 9.0 8.2	stopped by gravel

A good to excellent stand of slender wheat, green needle, prairie june, and side-oats grama. One colony of buffalo grass (buchloe dactyloides) and scattered spots of little bluestem grass and big sage. Scattered small forbs are common. The surface soil is moderately eroded along slope breaks, (% area).

(Salinity and Alkalinity starts at 64")

(Instructions inside back cover)

Form 7310-9 (December 1970)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION–SOIL DESCRIPTION

1. State 25
2. District 02
3. Planning Unit 12
4. Vegetation–Soil Unit mixed grasses - - / - 9002 -
5. Soil Map Symbol ~~C3N~~ B2
6. Surname - - - - Ward
7. Date 07 mo 74 yr
8. Area 1
9. County 075
10. Location Sec. - - 2, T. - 4 S, R. 45E
11. Photo No. - - - - - - - - - -
12. Writeup No. - - - 9
13. File No. - - - - - -
14. Parent Rock Alluvium and colluvium
15. Formation Name Fort Union
16. Surface Conditions (percent) Stone – 1 Rock – –
17. Land Conditions Alkaline Low to mod (subsoil) Saline low to mod (subsoil) Water table 710'
18. Landform Rolling hills
19. Slope (percent) 4/8 ☒ Single ☐ Complex
20. Aspect SW
21. Elevation - 3120'
22. Present Erosion Type SSF - - - Class 3
23. Hydrologic Group -
24. Precipitation (in) 13.7 1st , 2nd , 3rd , 4th
25. Temperature – – Air – – Soil
26. Frost-free 1130 Days – – – > 28°
27. Drainage Class Mod. well drained
28. Infiltration moderate
29. Percolation Mod. to slow
30. ERD 15 in
31. AWC 10.0 in

32. HORIZON	33. THICKNESS	34. COLOR DRY / MOIST		35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH) Lime	42. BOUNDARY
		MATRIX	MOTTLING								
A1	0-2	D-(10YR 7/2) m-(10YR 5/3)		SiCL	platy	D-Sli hard m- friable	None	many		N	Abrupt
B2	2-6	D-(10YR 7/3) m(10 YR 5/3)		SiCL	strong coarse prismatic	D- hard m- firm	None	many		N 8.4 7.7	clear wavy
B3CA	6-22	D(2.5 YR 7/4) m-(2.5YR 6/2)	lime on peds, ~~and in pockets~~,	SiCL	med ang. blky	D- Sli hard m- friable	None	many to com.	10	+++ 8.3 7.8	gradual
C1CA	22-40	D-(10YR 7/4) m-(10 YR 5/3)	~~threads~~, and pockets of lime	SiCL	massive	D Hard m- friable		Com. to few		+++ 9.1 8.1	
C2CA	40-60	D (2.5Y 7/2) m-(2.5Y 4/3)	lime in small pockets	SiC		m- friable		few to		+++ 8.9 8.2	
C3CA	60-90	D (10YR 7/2) m-(10YR 4/3)		Lt SiCL		m friable		none		+++ 8.7 8.2	
C4CA	90-120	D- (10YR 7/2) m (10YR 6/3)		Lt fSCL		m- friable				+++ 8.4 8.1	

A fair to good stand of prairie june, slender wheat, green needle and western wheatgrass. Forbes include broomweed, cheatgrass, prickley pear, and threadleaf sedge. Big and silver sage occur in scattered stands.

(Salinity and alkalinity starts at 40")

(Instructions inside back cover)

Form 7310–9 (December 1970)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION-SOIL DESCRIPTION

1. State 25
2. District 02
3. Planning Unit 12
4. Vegetation-Soil Unit mixed grasses - 9004
5. Soil Map Symbol 04/D3A1
6. Surname Ward
7. Date 02 mo 74 yr
8. Area --
9. County 075
10. Location Sec. 2, T. 4S, R. 45E
11. Photo No ----------
12. Writeup No. 8
13. File No. ------
14. Parent Rock Sandstone + shale
15. Formation Name Fort Union
16. Surface Conditions (percent) Stone – 0 Rock – 0
17. Land Conditions Alkaline slight (subsoil) Saline Non Water table > 5'
18. Landform Rolling hills
19. Slope (percent) 4/8 ☒ Single ☐ Complex
20. Aspect SW
21. Elevation 3120'
22. Present Erosion Type SSF --- Class 3
23. Hydrologic Group –
24. Precipitation (in) 13.7 1st , 2nd , 3rd , 4th
25. Temperature -- Air -- Soil
26. Frost-free Days 130 --> 28°
27. Drainage Class well drained
28. Infiltration High
29. Percolation moderate
30. ERD 16 in
31. AWC 10.0 in

32. HORIZON	33. THICKNESS	34. COLOR DRY MOIST MATRIX	34. MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL	41. REACTION (pH)	42. BOUNDARY
A1	0-2	D-(10YR 7/3) m-(10YR 4/2)		L	platy	D-soft m-friable	None	Many		N	Abrupt
B2CA	2-9	D-(10YR 7/3) m-(10YR 6/2)		L	med wk prismatic to fine granular	D-Hard m-friable	none	many		+++ 8.4 7.7	gradual
B3CA	9-16	D-(10YR 7/3) m-(10YR 5/3)		lt fSCL	weak prismatic to med fi gran	D-Sli hard m-friable	None	many to com.		+++ 8.6 7.9	gradual
C1CA	16-40	D-(10YR 7/1) m-(10YR 6/3)		lt CL	massive	D Hard m-friable		com to few		+++ 9.3 8.1	
C2CA	40-60	D-(10YR 7/2) m-(10YR 6/4)		fSL	weak massive	D soft m-friable		few to none		+++ 9.3 8.2	

A fair to good stand of prairie june, needle and thread, slender wheat, and green needle grass occupies most of the area. Prickley pear, big and silver sage occur in scattered stones. These soils are moderately susceptable to concentrated flow of water. Headward erosion is still act[illegible] short gullies. Water originates in a shallow soil area upsi[illegible]

(slight alkalinity below 16")

(Instructions inside back cover)

Form 7310-9 (December 1970)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION–SOIL DESCRIPTION

1. State 25
2. District 02
3. Planning Unit 12
4. Vegetation–Soil Unit Mixedgrasses, 90010
5. Soil Map Symbol 810/132N
6. Surname Ward
7. Date 07 mo 74 yr
8. Area 1
9. County 075
10. Location Sec. 2, T. 4S, R. 45E
11. Photo No. ----------
12. Writeup No. 9
13. File No. ------
14. Parent Rock Colluvium and alluvium
15. Formation Name Fort Union
16. Surface Conditions (*percent*) Stone 0 Rock 0
17. Land Conditions Alkaline Non Saline mod (subsoil) Water table > 10'
18. Landform Colluvial foot slopes bordering valley
19. Slope (*percent*) 2/4 ☒ Single ☐ Complex
20. Aspect SW
21. Elevation 3115'
22. Present Erosion Type Sheet SSF --- Class 2
23. Hydrologic Group -
24. Precipitation (*in*) 13.7 1st , 2nd , 3rd , 4th
25. Temperature -- Air -- Soil
26. Frost-free Days 130 > 28°
27. Drainage Class mod. well drained
28. Infiltration mod. to slow
29. Percolation mod. to slow
30. ERD 15 in
31. AWC 10.2 in

32. HORIZON	33. THICKNESS	34. COLOR DRY MOIST MATRIX	34. COLOR MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH) 1-5 CaCl2	42. BOUNDARY
A1	0-2	D-(10YR 7/2) m-(10YR 6/3)		CL	fine granular	D-soft m-friable	None	many		N	Clear wavy
B2	2-12	D-(10YR 6/3) m (10YR 5/3)		CL	med prismatic	D-Hard m-firm	None	many		N 8.4 7.7	abrupt
C1CA	12-36	D-(10YR 7/1) m-(10YR 5/2)	Lime on ped faces + sml pockets	CL	Prismatic to med fine granular	D-Sli hard m-friable	None	many to few		+++ 8.6 7.9	diffuse
C2CA	36-60	D-(10YR 8/3) m (10YR 6/3)	Lime on most ped faces and in pockets	Si CL	cotmed ang blocky	D-Sli hard m-firm		few to none		+++ 8.4 8.0	gradual
C3CA	60-72	D-(10YR 8/3) m-(10YR 7/4)	Lime on gravel and peds	Si CL	massive	D-Hard m-very firm		None	27	+++ 8.6 8.1	abrupt
C4CA	72-110	D (10YR 8/3) m (10YR 6/3)	Lime on ped faces and sml. pockets	Si C	Vert. cleavage Ang blk,	D-Hard m-very firm		None		++ 8.8 8.2	

(Sampled with push core)

A fair to good stand of western wheat, prairie june, and needle and thread grass covers the area. Growth is only fair. A combination of relatively slow infiltration and slope reduce amount of water stored for plant growth. Scattered big sage plants are common. Delineation includes a short escarpment joining the valley alluvium. Some indications of sodium were noted near the slope break and in eroded spots along the scarp.

(Salinity starts at 36")

(*Instructions inside back cover*)

Form 7310-9 (December 1970)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION–SOIL DESCRIPTION

1. State 25	2. District 02	3. Planning Unit 12	4. Vegetation–Soil Unit mixed grasses - 9001	5. Soil Map Symbol 01 ~~AIM~~	6. Surname Ward	7. Date 07 mo 74 yr
8. Area –	9. County 075	10. Location Sec. 2, T. 4S, R. 45E	11. Photo No.	12. Writeup No. 10	13. File No.	14. Parent Rock Alluvium
15. Formation Name Fort Union	16. Surface Conditions (percent) Stone – 0 Rock – 0	17. Land Conditions Alkaline Non Saline Non Water table > 14'				18. Landform Creek flood plain
19. Slope (percent) 0 to 2 ☐ Single ☒ Complex	20. Aspect W	21. Elevation 3085'	22. Present Erosion Type SSF – Class 1			23. Hydrologic Group
24. Precipitation (in) 13.7 1st, 2nd, 3rd, 4th	25. Temperature – Air – Soil	26. Frost-free Days 130 > 28°	27. Drainage Class Very well drained	28. Infiltration Moderate	29. Percolation mod. to high	30. ERD 19 in / 31. AWC 9.0 in

32. HORIZON	33. THICKNESS	34. COLOR DRY / MOIST – MATRIX	34. MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH) 1-5 CaCl2	42. BOUNDARY
A1	0-2	D- (10YR 7/4) m- (10YR 6/3)		fSL	platy	D- Soft m- friable	None	many			Clear smooth
AC	2-12	D- (10YR 7/4) m (10YR 6/3)		fSL	weak massive	D- Hard m- friable	None	many		++ 8.5 7.7	abrupt
C1CA	12-36	D- (10YR 7/2) m- (10YR 6/3)		fSL	week massive	D + Soft m- friable	None	many ~~few~~		++ 8.7 7.9	gradual
C2CA	36-51	D- (10YR 7/3) m- (10YR 5/3)		Hv fSL		m- friable		com to few		+++ 8.5 7.9	
C3CA	51-84	D- (10YR 6/4) m- (10YR 4/3)		Lt CL		m- friable		Very few to none		+++ 8.4 79	
C4CA	84-96	D- (10YR 6/4) m- (10YR 4/3)		Lt CL		m- friable				+++	
C5	96-120	D- (10YR 7/2) m- (10YR 5/4)		fSL		m- friable			5 Scav	++ 8.7 8.1	

A good stand of western wheat, needle and thread, and green needle grow in association with good to moderate cover of silver sage. The creek channel is sharply incised and is about 9 feet deep. sweetclover, timothy and smooth brome grass are common along the channel edge. Scattered patches of buck-brush and a few large cottonwood dot the valley. An attempt was made to determine the depth of the alluvial fill. Sand and pea gravel were encountered and the maximum depth was about 15 feet.

(Instructions inside back cover)

Form 7310–9 (December 1970)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION–SOIL DESCRIPTION

1. State 25
2. District 02
3. Planning Unit 12
4. Vegetation–Soil Unit mixed grasses, 9004
5. Soil Map Symbol 84 / DTA
6. Surname Ward
7. Date 07 mo 74 yr
8. Area --
9. County 075
10. Location Sec. 2, T. 4S, R. 45E
11. Photo No.
12. Writeup No. 11
13. File No.
14. Parent Rock Alluvium
15. Formation Name Fort Union
16. Surface Conditions (percent) Stone – 0 Rock – 0
17. Land Conditions Alkaline Non Saline Non Water table > 10'
18. Landform Terrace - elevation about 12' above flood plain
19. Slope (percent) 0/2 ☒ Single ☐ Complex
20. Aspect N
21. Elevation 3095'
22. Present Erosion Type SSF Class 1
23. Hydrologic Group –
24. Precipitation (in) 13.7 1st, 2nd; 3rd, 4th
25. Temperature -- Air -- Soil
26. Frost-free Days 130 > 28°
27. Drainage Class Very well drained
28. Infiltration Mod to high
29. Percolation Moderate
30. ERD 22 in
31. AWC 11.0 in

32. HORIZON	33. THICKNESS	34. COLOR DRY/MOIST MATRIX	MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH) 1-5 CaCl2	42. BOUNDARY
A1	0-2	D-(10YR 7/2) m(10YR 5/2)		fSL	platy	D-soft m-friable	None	many	None	N 7.7 7.0	Clear smooth
B1	2-8	D-(10YR 5/2) m-(10YR 3/1)		LtCL	med + fine gran	D Hard m friable	Non	many		N 7.6 7.1	diffuse
B2	8-22	D-(10YR 7/2) m(10YR 5/3)		LtCL	mod prismatic to fine ang blky	D Sli Hard m friable	Non	many		++ 8.1 7.4	diffuse
C1	22-30	D-(10YR 7/2) m-(10YR 5/3)	Lime in threads	LtCL	weak prismatic to mod fine [illegible]	D-Sli Hard m-friable	None	many to com		++ 8.2 7.6	clear wavy
C2CA	30-44	D-(10YR 7/3) m-(10YR 5/3)	Lime on peds and in threads	Hv fSL		D-soft m friable		com to few		+++ 8.5 7.8	
C3CA	44-58	D-(10YR 7/3) m-(10YR 4/4)	lime on some peds	SiL		D-Sli Hard m-friable				+++ 8.5 7.8	
C4CA	58-64	D-(10YR 7/4) m (10YR 5/3)	lime on peds and in sml pockets	HvSiL		D-sli hard m-friable				+++ 8.7 8.0	

A good to excellent stand of western wheat, green needle, prairie june and fescue grass provide a good cover for the area. Silver sage colonies of moderate size are common. Cheat and other minor forbes occur largely near the terrace front. This profile exhibits the highest level of profile development with respect to biotic activity.

(Instructions inside back cover)

Form 7310-9 (December 1970)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION–SOIL DESCRIPTION

1. State 25
2. District 02
3. Planning Unit 12
4. Vegetation–Soil Unit mixed grasses / 9003
5. Soil Map Symbol 03 / D3N
6. Surname Ward
7. Date 02 mo 74 yr
8. Area –
9. County 075
10. Location Sec. 2, T. 4S, R. 45E
11. Photo No –
12. Writeup No. 12
13. File No. –
14. Parent Rock Colluvium/residium
15. Formation Name Fort Union
16. Surface Conditions (percent) Stone – 1 Rock – –
17. Land Conditions Alkaline mod (subsoil) Saline High (subsoil) Water table > 6'
18. Landform Residual/colluvial slopes in rolling hills
19. Slope (percent) 6/18 ☒ Single ☐ Complex
20. Aspect S
21. Elevation 3115'
22. Present Erosion Type SSF – – – Class 3
23. Hydrologic Group –
24. Precipitation (in) 13.7 1st, 2nd, 3rd, 4th
25. Temperature – – Air – – Soil
26. Frost-free Days 130 > 28°
27. Drainage Class Mod. well drained
28. Infiltration Moderate
29. Percolation slow
30. ERD 12 in
31. AWC 6.0 in

32. HORIZON	33. THICKNESS	34. COLOR DRY / MOIST MATRIX	34. MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL	41. REACTION (pH) 1-5 CaCl2 W	42. BOUNDARY
A1	0-2	D- (10YR 7/2) m- (10YR 6/3)		Lt SiCL	Blocky (ang) to fine gran	D- Hard m- friable	None	many			clear
AC	2-16	D- (10YR 7/2) m- (10YR 5/3)		Lt SiCL	st med to co Blocky	D- Hard m firm	None	many		+ 8.6 7.8	abrupt
C1	16-30	D- (10YR 7/3) m- (10YR 6/3)	slight lime on peds	SiCL	fragments (massive)	D- Hard m firm	None	com. to few		++ 8.3 8.0	gradual
C2CA	30-40	D- (10YR 8/1) m- (10YR 6/4)	Lime in small pockets	Hv SiCL		m- very firm		few		+++ 8.6 8.3	
C3	40-64	D ( ) m (2.5YR 5/4)	few small pockets of lime	SiC		D- Hard m- very firm		few to None		++ 8.5 8.3	

A fair to good stand of western wheat, green needle and prairie june grass cover the area. Cheat grass and big sage are common. This complex slope is composed very steep slopes near the ridge top and knobs of shale and rock interspersed by shallow (rill) drains throught the mid and lower slopes. Stones are not uncommon but largely occur near rock outcrops or at the slope break between the upper and lower slope.

{ Salinity and alkalinity starts at 16" }

(Instructions inside back cover)

Form 7310–9 (December 1970)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION–SOIL DESCRIPTION

1. State 25
2. District 02
3. Planning Unit LZ
4. Vegetation–Soil Unit mixed grasses, 9006
5. Soil Map Symbol 06/FZM
6. Surname Ward
7. Date 02 mo 74 yr
8. Area --
9. County 075
10. Location Sec. 2, T. 4S, R. 45E
11. Photo No. ----------
12. Writeup No. 13
13. File No. ------
14. Parent Rock Alluvium (local)
15. Formation Name Fort Union
16. Surface Conditions (percent) Stone – 0 Rock – 0
17. Land Conditions Alkaline slight (subsoil) Saline Mod to high (subsoil) Water table > 10'
18. Landform Narrow valley floor in rolling hills
19. Slope (percent) 2-4 ☒ Single ☐ Complex
20. Aspect S
21. Elevation 3115'
22. Present Erosion Type SSF – Class 2
23. Hydrologic Group –
24. Precipitation (in) 13.7 1st , 2nd , 3rd , 4th
25. Temperature – – Air – – Soil
26. Frost-free Days 130 > 28°
27. Drainage Class Well drained
28. Infiltration Moderate
29. Percolation Mod to High
30. ERD 18 in
31. AWC 9.2 in

32. HORIZON	33. THICKNESS	34. COLOR DRY MOIST: MATRIX	MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH) 1-5 CaCl2	42. BOUNDARY
A2	0-2	D (10YR 7/2) m (10YR 5/3)		Lt L	platy	D-Soft m-friable	None	many		N	abrupt
B1A	2-7	D-(10YR 7/3) m-(10YR 5/3)		Lt L	prismatic	D-Hard m-friable	None	many		N 8.4 7.5	wavy
B2	7-16	D-(10YR 7/1) m-(10YR 5/2)	lime on peds few sml. pockets	Lt CL	prismatic	D-Hard m-friable	None	many		++ 8.3 7.8	abrupt
C1CA	16-36	D-(10YR 8/1) m-(10YR 6/4)	lime on peds and in pockets	Lt SiCL	Ang blky	D Hard m-friable		Many to Com.		+++ 8.5 8.2	diffuse
C2CA	36-48	D-(10YR 8/1) m-(10YR 4/4)	Lime on peds and in pockets	SiL	ang blky	D Hard m-friable		Com to few		+++ 8.6 8.4	
C3CA	48-72	D-(10YR 7/3) m-(10YR 4/4)	Lime on peds and in pockets	SiL		D Soft m-friable		few to None		+++ 8.6 8.4	
C4CA	72-84	D-(10YR 7/3) m-(10YR 6/4)	Lime on peds and in pockets	Lt FSCL		m-friable				+++ 8.6 8.3	
C5CA	84-108	D-(10YR 8/1) m-(10YR 7/4)		Lt SCL		m-friable			26	+++ 8.5 8.2	
C6CA	108-116	D-(10YR 8/2) m-(10YR 7/4)	Lime on peds + sm pockets	Lt CL		m-friable			5	+++ 8.5 8.2	

An excellent stand of western wheat grass, blue grama, green needle, needle and thread, and prairie june grass covers the area. Silver sage occurs randomly along the valley. Salinity is attribu to erosional of the valley slopes prior to the establishment of the present regime of relatively stable level of erosion. (Salinity starts at 16" and alkalinity at 36")

(Instructions inside back cover)

Form 7310-9 (December 1970)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION–SOIL DESCRIPTION

1. State 25
2. District 02
3. Planning Unit 12
4. Vegetation–Soil Unit mixed grasses, 9003
5. Soil Map Symbol 03/C2N
6. Surname Ward
7. Date 02 mo 2
8. Area –
9. County 075
10. Location Sec. 2, T. 4S, R. 45E
11. Photo No. ----------
12. Writeup No. 14
13. File No. ------
14. Parent Rock Colluvium and residium
15. Formation Name Fort Union
16. Surface Conditions (percent) Stone – 0 Rock – 0
17. Land Conditions Alkaline Non Saline Non Water table > 4'
18. Landform Residual slope in rolling hills
19. Slope (percent) 3–10 ☐ Single ☒ Complex
20. Aspect E
21. Elevation 3130
22. Present Erosion Type SSF Class 2
23. Hydrologic Group –
24. Precipitation (in) 13.7 1st, 2nd, 3rd, 4th
25. Temperature – – Air – – Soil
26. Frost-free Days 130 > 28°
27. Drainage Class Mod. well-drained
28. Infiltration Mod to high
29. Percolation Very slow
30. ERD 15 in
31. AWC 6.8 in

32. HORIZON	33. THICKNESS	34. COLOR DRY / MOIST: MATRIX	34. COLOR DRY / MOIST: MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL	41. REACTION (pH) lime	42. BOUNDARY
AC	0-8	D (10YR 5/3) m (10YR 3/4)		Lt L	fine to med granular	D- Soft m- friable	none	Many	Many large 3-6" to 5m	++ 8.5 7.7	abrupt
C1	8-18	D-(10YR 6/2) m-(10YR 5/1)	D- (10YR 8/6) m- (10YR 7/8)	Lt C	Ang blky	D- Sli Hard m- firm	None	many		++ 8.5 7.8	clear
C2CA	18-28	D- (10YR 7/3) m- (10YR 6/2)	Lime in pockets	Lt C	massive	m- firm	none	many to com		+++ 8.4 8.0	Clear wavy
C3CA	28-38	D- (10YR 6/3) m- (10YR 4/1)	Lime in pockets	MC	massive	m- v firm		com to few		+++ 8.6 8.0	Abrupt
C4CS	38-43	D- (2.5Y 4/0) m- (2.5Y 2/0)		MC	weathered layered shale	m v firm				Non 8.6 8.0	
C5CS	43-46	D- (2.5Y 5/0) m- (2.5Y 3/2)		CL		m. friable				+++	

A good stand of little bluestem, side-oats grama, and slender wheat grass covers the area. Big sage occurs in small groups and in the adjacent delineation on the upper slopes a few ponderosa pine dot the area. Several natural drains cross the area between weak ridges.

(Instructions inside back cover)

Form 7310–9 (December 1970)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION–SOIL DESCRIPTION

1. State 25
2. District 02
3. Planning Unit 12
4. Vegetation–Soil Unit mixed grasses, 9003
5. Soil Map Symbol 03/C2N
6. Surname Ward
7. Date 02 mo 74 yr
8. Area --
9. County 025
10. Location Sec. 2, T. 4, R. 45E
11. Photo No. ----------
12. Writeup No. 15
13. File No. ------
14. Parent Rock alluvium and inter-bedded siltstone and shale
15. Formation Name Fort Union
16. Surface Conditions (*percent*) Stone – 0 Rock – 0
17. Land Conditions Alkaline slight (subsoil) Saline High (subsoil) Water table > 6'
18. Landform alluvial fan and colluvial slope
19. Slope (*percent*) 3/8 ☐ Single ☒ Complex
20. Aspect SW
21. Elevation 3240'
22. Present Erosion Type SSF – – – Class 2
23. Hydrologic Group –
24. Precipitation (*in*) 13.7 1st, 2nd, 3rd, 4th
25. Temperature – – Air – – Soil
26. Frost-free Days 130 > 28°
27. Drainage Class Well-drained
28. Infiltration Moderate
29. Percolation Mod to Slow
30. ERD 15 in
31. AWC 6.5 in

32. HORIZON	33. THICKNESS	34. COLOR DRY / MOIST MATRIX	34. MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH) 1-5 CaCl₂	42. BOUNDARY
A1	0-2	D-(10YR 4/3) m-(10YR 5/4)		SiL	Crumb	D soft m v friable	none	many			clear
AC	2-16	D (10YR 5/6) m(10YR 4/3)		SiL	med sub-angular blocky	D soft m friable	none	many		7.9 7.5	abrupt
C1	16-36	D (10YR 5/4) m(10YR 4/3)		CL	weak massive	D-sl. Hard m-friable	none	many to com.		8.6 7.9	clear wavy
C2	36-64	D (10YR 7/2) m(10YR 5/3)		CL		D Hard m firm		few to none		8.1 8.1	

A good stand of bluegrama, prairie june, side-oats grama, western wheat, and green needle covers the upper slopes of the area. Big sage occurs randomly. The colluvial surface soils was derived in part from old alluvium and residum. Deeper soils are found along natural drains.

(Salinity and alkalinity starts 36")

(*Instructions inside back cover*)

Form 7310–9 (December 1970)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION–SOIL DESCRIPTION

1. State 25
2. District 02
3. Planning Unit 12
4. Vegetation–Soil Unit Mixed grasses, 9002
5. Soil Map Symbol 03 / C2N
6. Surname Ward
7. Date 02 mo 74 yr
8. Area --
9. County 025
10. Location Sec. 2, T. 4S, R. 45E
11. Photo No. ----------
12. Writeup No. 16
13. File No. ------
14. Parent Rock Colluvium and inter-bedded siltstone + shale
15. Formation Name Fort Union
16. Surface Conditions (percent) Stone – 0 Rock < 0
17. Land Conditions Alkaline mod (subsoil) Saline High (subsoil) Water table >25'
18. Landform Colluvial slope in Rolling hills
19. Slope (percent) 1/8 ☒ Single ☐ Complex
20. Aspect NW
21. Elevation 3140'
22. Present Erosion Type SSF --- Class –
23. Hydrologic Group –
24. Precipitation (in) 13.7 1st , 2nd , 3rd , 4th
25. Temperature -- Air -- Soil
26. Frost-free Days 130 > 28°
27. Drainage Class Mod. Well-drained
28. Infiltration Slow
29. Percolation Very slow
30. ERD 12 in
31. AWC 9.0 in

32. HORIZON	33. THICKNESS	34. COLOR DRY / MOIST MATRIX	MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL	41. REACTION (pH) 1-5 CaCl2	42. BOUNDARY
A1	0-2	D-(10YR 7/2) m-(10YR 5/3)		Lt CL	Platy	D soft m friable	None	many	None		Abrupt
B2	2-12	D-(10YR 6/2) m-(10YR 4/1)		CL	Med Ang Blocky	D- Hard m- firm	none	many	none	8.5 7.7	wavy
C1	12-18	D (10YR 7/3) m (10YR 5/4)		Lt C	Stratified gravelley	D- Hard m- firm		many		8.3 8.0	Clear wavy
C2	18-36	D- (10YR 6/2) m- (10YR 4/1)		Lt C	Mod angular blocky	D- Hard m- firm		Common		8.0 8.1	
C3	36-60	D-(2.5Y 6/3) m-(2.5Y 5/4)		Lt C		D- Hard m- firm		few		8.2 8.2	
C4	60-84	D-(10YR 7/1) m-(10YR 6/2)		Lt C		D Hard M firm				8.2 8.2	

A fair to good stand of slender wheat, prairie june, and western wheatgrass cover the area. Big sage cacti are abundant and salt tolerant sedge occasionally invade the area along the upper slopes. This soil is moderately erosive. rills become gullies. A deeply incised gully forms the NW boundary, it is 25 feet deep. A check was made of the strata per lower layer in an active side gully. This material is [illegible] in texture, moderately [illegible], [illegible] and moderately saline. (Salinity and Alkali [illegible] starts at 18")

(Instructions inside back cover)

Form 7310–9 (December 1970)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION–SOIL DESCRIPTION

1. State 25
2. District 02
3. Planning Unit 12
4. Vegetation–Soil Unit [illegible] / [illegible]
5. Soil Map Symbol 04/A1m
6. Surname Ward
7. Date 28 mo 74 yr
8. Area —
9. County 075
10. Location Sec. 2, T. 4S, R. 45E
11. Photo No. ——
12. Writeup No. 18
13. File No. ——
14. Parent Rock Alluvium and Interbedded siltstone and shale
15. Formation Name Fort Union
16. Surface Conditions (percent) Stone – 0 Rock – 0
17. Land Conditions Alkaline Non Saline Non Water table > 11'
18. Landform Low Alluvial terrace
19. Slope (percent) 0-2 ☒ Single ☐ Complex
20. Aspect N
21. Elevation 3095'
22. Present Erosion Type SSF — Class 1
23. Hydrologic Group —
24. Precipitation (in) 13.7 1st , 2nd , 3rd , 4th
25. Temperature — Air — Soil
26. Frost-free Days 131 > 28°
27. Drainage Class Very well-drained
28. Infiltration Moderate
29. Percolation [illegible]
30. ERD 22 in
31. AWC 11.2 in

32. HORIZON	33. THICKNESS (in)	34. COLOR DRY/MOIST MATRIX	MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH) 1-5 CaCl2	42. BOUNDARY
A1	0-2	D-(10YR 7/2) m-(10YR 5/2)		fsL	platy	D-soft m-friable	None	many		N –	Abrupt
B1	2-8	D (10YR 5/2) m (10YR 3/1)		Lt CL	med and fine granular	D-Hard m-friable	None	many		N 7.0 7.0	diffuse
B2	8-20	D-(10YR 7/2) m-(10YR 5/3)		Lt. CL	med prismatic	D-Sli Hard m-friable	None	many		++ 7.9 7.5	diffuse
C1	20-30	D-(10YR 7/2) m-(10YR 5/3)	Lime in threads	Lt CL	Weak Prismatic to m+f gran	D-Sli Hard m-friable		many to com		++ 7.7 7.5	clear wavy
C2CA	30-44	D-(10YR 7/3) m-(10YR 5/3)	Lime on peds and in threads	Hv fsL		D-soft m-friable		com. to few		+++	
C3CA	44-54	D-(10YR 7/3) m (10YR 6/4)	Lime on few peds	S. L		D-Sli Hard m-friable		few to None		+++ 8.5 7.7	
C4CA	54-76	D (10YR 7/3) m (10YR 5/2)	Lime on peds and small pockets	Hv siL		D-Sli Hard m-friable				++ 8.5 7.9	
C5CA	76-92	D (10YR 7/3) m (10YR 6/3)		fsL		m-friable				8.4 7.9	
C6CA	92-120	D-(10YR 7/3) m-(10YR 6/4)		fsL		m-friable				8.5 7.9	

This profile sampled near Profile No. 11 for use in greenhouse [illegible]
See # 11 for general description.

(Instructions inside back cover)

Form 7310-9 (December 1970)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION–SOIL DESCRIPTION

1. State 25
2. District 02
3. Planning Unit 12
4. Vegetation–Soil Unit Mixed grasses - - 1003
5. Soil Map Symbol 03/E3N
6. Surname Ward
7. Date 07 mo 74 yr
8. Area --
9. County 025
10. Location Sec. 2, T. 4S, R. 45E
11. Photo No. ----------
12. Writeup No. 19
13. File No. ------
14. Parent Rock colluvium & residum from interbedded shale
15. Formation Name Fort Union
16. Surface Conditions (percent) Stone -- Rock --
17. Land Conditions Alkaline Non Saline Non Water table > 5'
18. Landform Foot slopes in rolling hills
19. Slope (percent) 8 - 50 ☐ Single ☒ Complex
20. Aspect NE
21. Elevation 3180'
22. Present Erosion Type SSF --- Class 3
23. Hydrologic Group -
24. Precipitation (in) 13.7 1st , 2nd , 3rd , 4th
25. Temperature -- Air -- Soil
26. Frost-free Days 130 28°
27. Drainage Class Mod well-drained
28. Infiltration Mod to high
29. Percolation slow
30. ERD 8 in
31. AWC 4.8 in

32. HORIZON	33. THICKNESS inches	34. COLOR DRY / MOIST MATRIX	34. MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL	41. REACTION (pH) 1-5 $CaCl_2$	42. BOUNDARY
A1	0-8	D(10YR 4/3) m(10YR 5/2)		CL	fine + mod granular	D soft m friable	None	many		N 8.0 8.1	Clear wavy
AC	8-10	D (2.5Y N6) m(2.5Y N3)		Lt C	subang Blky	D sli hard m friable	None	many		++ 8.4 7.6	gradual
C1	10-24	D (2.5Y N4/) m(2.5Y N2/)		C	Layered shale	D hard m sli firm	None				

An excellent stand of side-oats grama, little bluestem, and prairie junegrass forms a good cover. Ponderosa pine occurs on the mid and lower slopes. It is absent on the alluvial remnants that now form knobs. The opposite SW facing slope across the coulee is shallow to silty shale. Vegetation consists largely of wheat grasses. Stand is sparse and the shale is not as highly weathered. Effective moisture for weathering the shale is reduced.

(Instructions inside back cover)

Form 7310–9 (December 1970)

Engineering Properties of Soils

			DEPTH TO				CORROSIVITY		CLASSIFICATION				PERCENTAGE PASSING SIEVE NUMBER				PERCENT		MOISTURE DENSITY	
MAP SYMBOL (1)	SOIL NAME (2)	DEPTH FROM SURFACE OF TYPICAL PROFILE (inches) (3)	BED-ROCK (4)	SEASONAL HIGH WATER TABLE (inches) (5)	HYDRO-LOGIC SOIL GROUP (6)	SHRINK-SWELL POTEN-TIAL (7)	UNCOATED STEEL (8)	CON-CRETE (9)	USDA TEXT. (10)	UNIFIED (11)	AASHO (12)	COARSE FRAC-TION (percent) (13)	4 (14)	10 (15)	40 (16)	200 (17)	LIQUID LIMIT (LL) (18)	PLASTI-CITY INDEX (PI) (19)	MAXIMUM DRY DENSITY (lbs cu ft) (20)	OPTIMUM MOISTURE (Percent) (21)
Site 2 9001	Hover-son	whole Profile	>216"	120"+	B	Low	High	Low												
		0-2							SiL	ML	A-4	23.3	100	100	97	84	38.0	11.5		
		2-8							SiL	CL	A-6	20.3	100	100	98	86	34.5	14.9		
		8-33							SiL	CL	A-6	29.3	100	100	99	80	27.9	8.7		
		33-49							L	ML-CL	A-4	47.0	100	100	93	67	25.5	5.1		
		49-60							VFSL	ML	A-4	60.6	100	100	94	58	20.7	1.9		
Site 6 9004	McRae	whole Profile	>120"	None	B	Low	Mod to High	Low												
		0-3							VFSL	ML-CL	A-4	54.2	100	100	94	62	26.6	5.6		
		3-6							VFSL	CL	A-6	52.3	100	100	95	63	30.0	13.1		
		6-20							L	CL	A-6	40.5	100	100	93	60	32.7	14.5		
		20-27							L	CL	A-6	36.3	100	100	93	75	30.2	13.4		
		27-40							L	CL	A-6	35.5	100	100	97	75	26.3	13.1		

Engineering Properties of Soils

MAP SYMBOL (1)	SOIL NAME (2)	DEPTH FROM SURFACE OF TYPICAL PROFILE (inches) (3)	DEPTH TO		HYDRO-LOGIC SOIL GROUP (6)	SHRINK SWELL POTEN-TIAL (7)	CORROSIVITY		CLASSIFICATION			COARSE FRAC-TION (percent) (13)	PERCENTAGE PASSING SIEVE NUMBER				PERCENT		MOISTURE DENSITY	
			BED-ROCK (4)	SEASONAL HIGH WATER TABLE (inches) (5)			UNCOATED STEEL (8)	CON-CRETE (9)	USDA TEXT (10)	UNIFIED (11)	AASHO (12)		4 (14)	10 (15)	40 (16)	200 (17)	LIQUID LIMIT (LL) (18)	PLASTI-CITY INDEX (PI) (19)	MAXIMUM DRY DENSITY (lbs.-cu.ft.) (20)	OPTIMUM MOISTURE (Percent) (21)
Site 1 9003	Midway	whole profile	<20	None	D	High	High													
		0-3							CL	CL	A-6	32.2	100	100	90	63	29.6	8.8		
		3-6							SiCL	CL	A-7	11.5	100	100	98	89	41.5	20.6		
		6-12							SiCL	CL	A-7	4.0	100	100	99	96	40.6	19.2		
		12-19							SiCL	CL	A-7	3.2	100	100	98	97	38.6	17.1		
		19-38							SiL	CL	A-6	2.5	100	100	99	97	33.1	13.4		
		38-60							SiL	CL	A-6	3.7	100	100	99	96	35.0	14.4		
Site 3 9002	Thurlow	whole Profile	20-60	None	B	Mod-High	Mod													
		0-3							SiC	CL	A-7	14.5	100	100	97	90	45.8	23.7		
		3-13							SiC	CL	A-7	13.7	100	100	98	90	46.2	26.8		
		13-18							SiC	CL	A-7	19.4	100	100	99	96	43.8	24.8		
		18-25							L	CL	A-6	28.2	100	100	99	80	34.2	15.5		
		25-40							L	CL	A-6	25.7	100	100	99	88	32.8	12.5		
		40-52							SiL	CL	A-6	16.7	100	100	99	88	33.8	16.2		
		52-60							SiCL	CL	A-7	11.8	100	100	100	91	41.8	25.8		

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

INTERPRETIVE RATINGS FOR SOIL USES

		SUITABILITY					DEGREE OF LIMITATION AND SOIL FEATURES AFFECTING														
							PONDS					AREAS									
MAP SYMBOL (1)	SOIL NAME (2)	DRYLAND FARMING (3)	IRRI-GATION (4)	TOPSOIL (5)	SAND/GRAVEL (6)	ROAD FILL (7)	LOCA-TION (9)	EMBANK-MENT (10)	ROAD LOCA-TION (11)	SHALLOW EXCAVA-TIONS (12)	BUILD-ING SITES (13)	CAMP (14)	PICNIC (15)	PLAY (16)	PATHS TRAILS (17)	SEPTIC TANK ABSORP-TION (18)	SEWAGE LAGOONS (19)	SANI-TARY LAND FILL (20)	LAWNS AND GOLF FAIR-WAYS (21)	LAND-SCAPE PLANT-ING (22)	OTHER over burden (23)
9001 01 A1M	Haverson 0-2% slope	Good	Good	Good	unsuited	Poor	slight to mod	Poor Comp-actabil	Fair	slight	mod	slight	slight	slight	slight	mod	mod	Severe	slight	slight	Good
9002 .02 A or B	Thurlow 0-12% S.	Good Here tracts are often too Smal	Unsuited drainage capability Poor - Shale	0-16" Good	unsuited	poor	slight to mod	Fair to Poor	Fair	slight to mod	slight to mod	mod.	mod.	mod	Mod.	mod.	Mod.	mod to Severe	slight to mod	mod	Good to Fair,
02 C3N	7-12% S.	Good	unsuited	0-12" Good	unsuited	Poor	severe	Poor to Severe	Poor	mod to severe	severe	severe	severe	mod to severe	severe	severe	severe	severe	severe	mod	Good to fair
9003 03 B+C	midway 3-12% S.	unsuited	unsuited	unsuited	unsuited	Poor	slight to mod	mod	Poor	severe	severe	Fair	mod.	Mod to Severe	Mod. to Severe	Severe	mod. to Severe	severe	Severe	severe	Poor to unsuited
03 D thru F	12-75% S.	unsuited	unsuited	unsuited	unsuited	Poor	Mod. to severe	Severe	Poor	severe	severe	poor to severe	Poor to Severe	severe	severe	severe	severe	Severe	severe	severe	unsuited
9004 04 A+B	McRae 0-7% slope	Good	Good	Good	Unsuited	Poor	slight	mod	fair to Good	slight	mod.	slight	slight	slight	slight	mod.	mod	mod	slight	slight	Good
04 C2M	7-12% slope	Good many tracts too small here	Good	Good	unsuited	poor	mod	mod	mod	mod	mod	mod	mod	severe	slight	mod	severe	mod	slight	slight	Good
9005 05 A+B	Lambeth 0-7% slope	Fair small tracts shallow shale	unsuited	0-13" Good	unsuited	poor	mod	Mod	Mod	mod to severe	mod	slight	slight	slight to mod	slight	mod to severe	mod to Severe	slight to mod	slight	slight to mod	Fair to Good
05 C2M	7-12% slope	Poor erosive	unsuited poor drain	0-12" Good	unsuited	Poor	mod	mod	mod to Severe	Mod to severe	mod	mod	Mod	severe	slight	mod to Severe	severe	slight to mod	slight to mod	Mod	Fair to Good
9006 06 A+B	unnamed 0-3% slope	Poor topographic.	unsuited	0-24" Good	unsuited	poor	mod	mod	Poor - location	Poor in natural drainageway	Poor	Poor	Poor	Poor	slight	mod	severe location	Severe	Severe	severe	Good to Fair

(continued on reverse)

Form 7310-21 (August 1971)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

INTERPRETIVE RATINGS FOR SOIL USES

MAP SYMBOL (1)	SOIL NAME (2)	SUITABILITY					DEGREE OF LIMITATION AND SOIL FEATURES AFFECTING															
		DRYLAND FARMING (3)	IRRIGATION (4)	TOPSOIL (5)	SAND/GRAVEL (6)	ROAD FILL (7)	PONDS		ROAD LOCATION (11)	SHALLOW EXCAVATIONS (12)	BUILDING SITES (13)	AREAS			PATHS TRAILS (17)	SEPTIC TANK ABSORPTION (18)	SEWAGE LAGOONS (19)	SANITARY LAND FILL (TRENCH) (20)	LAWNS AND GOLF FAIRWAYS (21)	LANDSCAPE PLANTING (22)	OTHER overburden (23)
							LOCATION (9)	EMBANKMENT (10)				CAMP (14)	PICNIC (15)	PLAY (16)							
9007 07 A+B	Unnamed 0-7% slopes	Poor Mod. shallow to shale and slick spots	unsuited	Poor	unsuited	Poor	Slight to Mod	Poor soil stability	Poor to Severe	Poor	Poor	mod to Severe	severe	severe	Slight to Mod	Severe	slight to mod	Mod to severe	unsuited	severe to unsuited	Poor
9008 08 A+B	Unnamed 0-7% slope	Fair to good	Poor to Unsuited	0-18" Good	unsuited	poor	mod to Severe	Poor	Fair	Poor to fair	Fair to Good	slight	slight	slight	Slight	slight	Mod to severe	mod to Severe	slight to mod	slight to mod	Good
9009 A+B	Unnamed 0-7% slopes	Fair to Good	unsuited to Poor	0-16" Good some slick spots	Unsuited	poor	mod	Fair to Poor	Poor	Fair to Poor	Fair to poor	slight	slight	slight	slight	Poor to Severe	Poor	slight to mod	slight to mod	slight to mod	Fair
9010 010 B2N	Heldt 3-7% slopes	Good	Good to Fair	0-18" Good	unsuited	Fair to Poor	Mod	Mod	Good	mod	slight	slight	slight	slight	Slight	slight to mod	Slight to Mod	slight to mod	Slight	Slight	Good
010 C3N	7-12% slopes	Good	Good to fair	0-18" Good	Unsuited	Fair to Poor	Mod	Fair	Fair	Slight to mod	slight to mod	slight to mod	Mod to Severe	Mod to Severe	Slight	slight to mod	mod to severe	Slight to mod	slight to Mod	Slight to Mod.	Good to Fair

(Continued on reverse)

Form 7310-21 (August 1971)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

INTERPRETIVE RATINGS FOR SELECTED SOIL PROPERTIES AND QUALITIES

MAP SYMBOL	SOIL NAME	CLASS				LIMITING LAYER		EFFECTIVE ROOTING DEPTH (in.)	AVAILABLE WATER CAPACITY (in.)	PRECIPITATION (in.)		FROSION		COMPACTION HAZARD (Class)	FREQUENCY OF FLOODING	REACTION RANGE (pH)	FROST SUSCEPTIBILITY (Class)
		DEPTH	PERMEABILITY	RUNOFF	DRAINAGE	KIND	THICKNESS (in.)			ANNUAL	EFFECT	CONDITION	SUSCEPTIBILITY (Class)				
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
9001.	Haverson	VD	MRAP	V SLOW	Exd			18	High	14		slight	slight	slight	ocal	7.6-9.0	High
9002.	Thurlow	MD	MRAP	MED	WED			18	High	14		mod	mod	mod	None	7.5-8.8	High
9003	Midway	VS	SLOW	RAP	WED	Shale		8	VLOW	14		mod severe	mod to severe	mod	None	7.8-9.2	mod.
9004	McRae	VD	MRAP	VSLOW	SED			16	High	14		Slight	slight	Slight	None	6.8-9.0	Mod
9005	Lambeth	S	MRAP	V SLOW	WED	Shale		13	Low	14		slight	slight	slight	None	6.6-9.0	High
9006	unnamed	VD	MRAP	Slow	WED			15	High	14		mod	mod	slight	ocal	7.3-9.0	High
9007	unnamed	MD	MSLOW	SLOW	WED			12	M High	14		mod	mod	slight	None	6.5-9.0	High
9008	unnamed	MD	MRAP	VSLOW	SED			15	M High	14		slight	slight	slight	None	6.6-8.5	mod to High
9009	unnamed	MD	MSLOW	SLOW	WED			13	M. High	14		Mod	Mod	Mod	None	7.6-9.0	Mod to High
9010	Heldt	VD	MSLOW	MED	WED			15	High	14		Mod	Mod	Mod	None	7.8-8.6	mod to High

Remarks

(Instructions on reverse)

Form 7310-21 (August 1973)

Watershed Management
Measurements and Interpretations

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

WATERSHED MANAGEMENT

MEASUREMENTS AND INTERPRETATIONS

MAP SYMBOL	SOIL NAME	SOIL LIMITATIONS TO VEGETATIVE MANIPULATION AND WATERSHED TILLAGE PRACTICES MECHANICAL EQUIPMENT USAGE											POT VEG GROUND COVER Percent	OTHER INTERPRETATION Mine Reclamation
		RANGELAND		CHAINING	CONTOUR FURROWING	RIPPING	PITTING	TERRACING	TRENCHING	WATERSPREADING		SEEDING		
		DRILL	DISC PLOW							CONSTRUCTION	IRRIGABLE			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
9001 01 A1M	Haverson 0-3%	slight	slight	NA	NA	NA	NA	NA	NA	mod.	Good 1/	slight	90-100	Excellent.
9002 02 A1N and B2N	Thurlow 0-7% slopes	slight	slight	NA	NA to slight	NA	NA to slight	NA	NA	slight	Good 2/	slight	90-100	Good
02 C3N	7-12% slopes	slight	slight	NA	slight	NA	NA	NA	NA	slight	Fair 2/	slight	80-100	Good
9003 03 B2N and B3H	Midway 3-7%	slight to mod.	mod to severe	NA	NA	NA	NA	NA	NA	slight to mod	Poor 2/	mod	75-90	Poor to Fair
03 C2M and C3N	7-12% slopes	slight to mod	slight to mod	NA	mod to severe	NA	NA	NA	NA	mod to severe	Poor 2/	mod	50-75	Fair to Poor
03+03S D344N E344N F344N	2-20% 20-35% 35-75%	severe	severe	NA	NA	NA	NA	NA	NA	severe	NA	mod to severe	50-60	poor /
9004 04 A1M and B2M	McRae 0-3% 3-7%	slight	slight	NA	NA	NA	NA	NA	NA	mod	Good 1/	slight	90-100	Good

NA — Not applicable
1/ suited for full production under sustained irrigation.
2/ suited for partial irrigation such as spreader dikes. - Is not suitable for full irrigation production

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

WATERSHED MANAGEMENT
MEASUREMENTS AND INTERPRETATIONS

MAP SYMBOL (1)	SOIL NAME (2)	SOIL LIMITATIONS TO VEGETATIVE MANIPULATION AND WATERSHED TILLAGE PRACTICES MECHANICAL EQUIPMENT USAGE: RANGELAND: DRILL (3)	RANGELAND: DISC PLOW (4)	CHAINING (5)	CONTOUR FURROWING (6)	RIPPING (7)	PITTING (8)	TERRACING (9)	TRENCHING (10)	WATERSPREADING: CONSTRUCTION (11)	WATERSPREADING: IRRIGABLE (12)	SEEDING (13)	POT VEG GROUND COVER (Percent) (14)	OTHER INTERPRETATION Mine Reclamation (15)
9004 04/C2M	McRae 7-12% slope	slight	Slight	NA	NA	NA	NA	NA	NA	Slight to mod	Good 1/	Slight	90-100	Excellent
9005 05/A1M and A2M	Lambeth 0-3% slopes	slight	slight	NA	NA	NA	NA	NA	NA	Slight to mod	Good 2/	slight	90-100	Fair to Good
05/C3M	7-12% slopes	slight	slight	NA	NA	NA	NA	NA	NA	Slight to mod	Fair 2/ to poor	slight	90-100	Fair to Good
9006 06/A2M and B2M	Unnamed	Severe Narrow flood-plain of small natural drains	Severe	NA	NA	NA	NA	NA	NA	Mod to severe	Poor	mod to severe	80-100	Good
9007 A2N and B2N	Un-named 0-3% 3-7% slopes	Slight	Slight	NA	NA	NA	NA	NA	NA	Mod to Severe	Poor 2/	Slight to mod	70-90	Fair to Poor

NA - Not applicable
1/ Suited for full production under sustained irrigation
2/ Suited for partial irrigation such as spreader dikes. - I, not suitable for full irrigation production

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Form 1279-3
(June 1984)

BORROWER'

TD 195 .S75 E4

Otter Creek st

DATE LOANED	BORROWER
5-13-87	Barry Cushing 8/3 Grand Juct. D.O. d

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